(19)日本国特許庁（ＪＰ）　(12) **公開特許公報**（Ａ）　(11)特許出願公開番号

特開2002－94141

（P2002－94141A）

(43)公開日　平成14年3月29日(2002.3.29)

(51)Int.Cl.[7]	識別記号	ＦＩ	テーマコート゛(参考)
Ｈ０１Ｌ　43/08		Ｈ０１Ｌ　43/08	Ｚ　２Ｇ０１７
Ｇ０１Ｒ　33/09		Ｇ１１Ｂ　5/39	５Ｄ０３４
Ｇ１１Ｂ　5/39		Ｈ０１Ｆ　10/16	５Ｅ０４９
Ｈ０１Ｆ　10/16		10/32	
10/32		Ｇ０１Ｒ　33/06	Ｒ

審査請求　有　請求項の数21　ＯＬ　（全 34 頁）

(21)出願番号　特願2000－366972(P2000－366972)

(22)出願日　平成12年12月1日(2000.12.1)

(31)優先権主張番号　特願2000－209462(P2000－209462)

(32)優先日　平成12年7月11日(2000.7.11)

(33)優先権主張国　日本（ＪＰ）

(71)出願人　000010098
アルプス電気株式会社
東京都大田区雪谷大塚町１番７号

(72)発明者　長谷川　直也
東京都大田区雪谷大塚１番７号　アルプス電気株式会社社内

(72)発明者　斎藤　正路
東京都大田区雪谷大塚１番７号　アルプス電気株式会社社内

(74)代理人　100085453
弁理士　野▲崎▼　照夫

Ｆターム(参考)　2G017 AA01 AB07 AD55 AD65
5D034 BA04 BA05 CA08 DA07
5E049 AA04 BA12 DB04 DB12 GC01

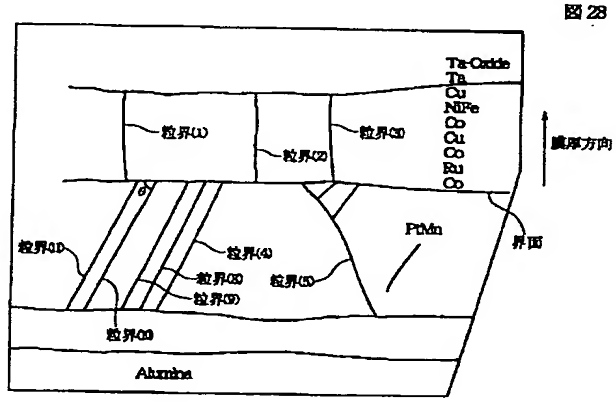
(54)【発明の名称】　交換結合膜と、この交換結合膜を用いた磁気抵抗効果素子、ならびに前記磁気抵抗効果素子を用いた薄膜磁気ヘッド

(57)【要約】

【目的】　耐食性に優れた反強磁性材料としてＰｔＭｎ合金膜が知られているが、前記ＰｔＭｎ合金膜を反強磁性層として使用しても、結晶粒界の状態によって交換結合磁界は小さくなることがわかった。

【構成】　本発明では、反強磁性層（ＰｔＭｎ合金膜）に形成された結晶粒界と、強磁性層に形成された結晶粒界が、界面の少なくとも一部で不連続な状態になっている。これによって前記反強磁性層は熱処理を施すことによって適切な規則変態を起しており、従来に比べて大きな交換結合磁界を得ることが可能である。

図28



【特許請求の範囲】
【請求項１】　反強磁性層と強磁性層とが接して形成され、前記反強磁性層と強磁性層との界面に交換結合磁界が発生し、前記強磁性層の磁化方向が一定方向にされる交換結合膜において、
前記反強磁性層は、元素Ｘ（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうち１種または２種以上の元素である）とＭｎとを含有する反強磁性材料で形成され、
前記交換結合膜を膜厚方向と平行な切断面に現われる前記反強磁性層に形成された結晶粒界と、強磁性層に形成された結晶粒界とが前記界面の少なくとも一部で不連続であることを特徴とする交換結合膜。
【請求項２】　前記反強磁性層及び強磁性層は、前記界面と平行な方向に[１１１]面として表される等価な結晶面が優先配向している請求項１記載の交換結合膜。
【請求項３】　反強磁性層と強磁性層とが接して形成され、前記反強磁性層と強磁性層との界面に交換結合磁界が発生し、前記強磁性層の磁化方向が一定方向にされる交換結合膜において、
前記反強磁性層は前記界面と平行な方向に[１１１]面として表される等価な結晶面が優先配向し、
前記反強磁性層には少なくとも一部に双晶が形成され、少なくとも一部の前記双晶の双晶境界は、前記界面と非平行に形成されていることを特徴とする交換結合膜。
【請求項４】　前記双晶境界と前記界面間の内角は、６８°以上で７６°以下である請求項３記載の交換結合膜。
【請求項５】　前記強磁性層は、前記界面と平行な方向に[１１１]面として表される等価な結晶面が優先配向している請求項３または４に記載の交換結合膜。
【請求項６】　前記反強磁性層は、元素Ｘ（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうち１種または２種以上の元素である）とＭｎとを含有する反強磁性材料で形成される請求項３ないし５のいずれかに記載の交換結合膜。
【請求項７】　前記交換結合膜は、下から反強磁性層、強磁性層の順に積層され、さらに前記反強磁性層の下側に、結晶構造が主として面心立方晶から成り、しかも前記界面と平行な方向に[１１１]面として表される等価な結晶面が優先配向したシードレイヤが形成されている請求項１ないし６のいずれかに記載の交換結合膜。
【請求項８】　前記シードレイヤは、ＮｉＦｅ合金、ＮｉあるいはＮｉ－Ｆｅ－Ｙ合金（ただしＹは、Ｃｒ，Ｒｈ，Ｔａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉから選ばれる少なくとも１種以上）、さらにはＮｉ－Ｙ合金で形成される請求項７記載の交換結合膜。
【請求項９】　前記シードレイヤは、組成式が $(Ni_{1-x}Fe_x)_{1-y}Y_y$（ｘ，ｙは原子比率）で示され、原子比率ｘは０以上で０．３以下で、原子比率ｙは０以上で０．５以下である請求項８記載の交換結合膜。
【請求項１０】　前記シードレイヤは常温で非磁性である請求項７ないし９のいずれかに記載の交換結合膜。
【請求項１１】　前記シードレイヤの下には、Ｔａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉ，Ｍｏ，Ｗのうち少なくとも１種以上の元素で形成された下地層が形成されている請求項７ないし１０のいずれかに記載の交換結合膜。
【請求項１２】　前記反強磁性層とシードレイヤとの界面の少なくとも一部は非整合状態である請求項７ないし１１のいずれかに記載の交換結合膜。
【請求項１３】　前記反強磁性層は、Ｘ－Ｍｎ－Ｘ′合金（ただし元素Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成されている請求項１ないし１２のいずれかに記載の交換結合膜。
【請求項１４】　前記Ｘ－Ｍｎ－Ｘ′合金は、元素ＸとＭｎとで構成される空間格子の隙間に元素Ｘ′が侵入した侵入型固溶体であり、あるいは、元素ＸとＭｎとで構成される結晶格子の格子点の一部が、元素Ｘ′に置換された置換型固溶体である請求項１３記載の交換結合膜。
【請求項１５】　前記元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は、４５（ａｔ％）以上６０（ａｔ％）以下である請求項１ないし１４のいずれかに記載の交換結合膜。
【請求項１６】　前記反強磁性層と強磁性層との界面の少なくとも一部は非整合状態である請求項１ないし１５のいずれかに記載の交換結合膜。
【請求項１７】　反強磁性層と、この反強磁性層と接して形成され、前記反強磁性層との交換異方性磁界により磁化方向が固定される固定磁性層と、前記固定磁性層に非磁性中間層を介して形成されたフリー磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向へ揃えるバイアス層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、請求項１ないし請求項１６のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。
【請求項１８】　反強磁性層と、この反強磁性層と接して形成され、前記反強磁性層との交換異方性磁界により磁化方向が固定される固定磁性層と、前記固定磁性層に非磁性中間層を介して形成されたフリー磁性層とを有し、前記フリー磁性層の上側または下側に、トラック幅Ｔｗの間隔を空けて反強磁性のエクスチェンジバイアス層が形成され、前記エクスチェンジバイアス層とフリー磁性層とが、請求項１ないし請求項１６のいずれかに記載された交換結合膜により形成され、前記フリー磁性層の磁化が一定方向にされることを特徴とする磁気抵抗効果素子。

【請求項１９】　フリー磁性層の上下に積層された非磁性中間層と、一方の前記非磁性中間層の上および他方の非磁性中間層の下に位置する固定磁性層と、一方の前記固定磁性層の上および他方の固定磁性層の下に位置して、交換異方性磁界によりそれぞれの固定磁性層の磁化方向を一定の方向に固定する反強磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向に揃えるバイアス層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、請求項１ないし請求項１６のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。

【請求項２０】　非磁性層を介して重ねられた磁気抵抗層と軟磁性層とを有し、前記磁気抵抗層の上側あるいは下側にトラック幅Ｔｗの間隔を空けて反強磁性層が形成され、前記反強磁性層と磁気抵抗層とが、請求項１ないし請求項１６のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。

【請求項２１】　請求項１７ないし２０のいずれかに記載された磁気抵抗効果素子の上下にギャップ層を介してシールド層が形成されていることを特徴とする薄膜磁気ヘッド。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、反強磁性層と強磁性層とから成り、前記反強磁性層と強磁性層との界面にて発生する交換結合磁界により、前記強磁性層の磁化方向が一定の方向に固定される交換結合膜に係り、特に大きい前記交換結合磁界を得られるようにした交換結合膜およびこの交換結合膜を用いた磁気抵抗効果素子（スピンバルブ型薄膜素子、ＡＭＲ素子）、ならびに前記磁気抵抗効果素子を用いた薄膜磁気ヘッドに関する。

【０００２】

【従来の技術】スピンバルブ型薄膜素子は、巨大磁気抵抗効果を利用したＧＭＲ（giant magnetoresistive）素子の１種であり、ハードディスクなどの記録媒体からの記録磁界を検出するものである。

【０００３】このスピンバルブ型薄膜素子は、ＧＭＲ素子の中でも比較的構造が単純で、しかも弱い磁界で抵抗が変化するなど、いくつかの優れた点を有している。

【０００４】前記スピンバルブ型薄膜素子は、最も単純な構造で、反強磁性層、固定磁性層、非磁性中間層およびフリー磁性層から成る。

【０００５】前記反強磁性層と固定磁性層とは接して形成され、前記反強磁性層と固定磁性層との界面にて発生する交換異方性磁界により、前記固定磁性層の磁化方向は一定方向に単磁区化され固定される。

【０００６】フリー磁性層の磁化は、その両側に形成されたバイアス層により、前記固定磁性層の磁化方向と交叉する方向に揃えられる。

【０００７】前記反強磁性層には、Ｆｅ－Ｍｎ（鉄－マンガン）合金膜、Ｎｉ－Ｍｎ（ニッケル－マンガン）合金膜、あるいはＰｔ－Ｍｎ（白金－マンガン）合金膜等が一般的に使用されているが、この中でも特にＰｔ－Ｍｎ合金膜はブロッキング温度が高く、しかも耐食性に優れるなど種々の優れた点を有しており、脚光を浴びている。

【０００８】

【発明が解決しようとする課題】ところで本発明者らは、反強磁性層にＰｔＭｎ合金膜を使用しても前記反強磁性層と固定磁性層間で発生する交換結合磁界は、条件によって大きくできないことがわかった。

【０００９】前記反強磁性層にＰｔＭｎ合金膜を使用した場合には、前記反強磁性層及び固定磁性層を積層した後、熱処理を施すことによって、前記反強磁性層を不規則格子から規則格子へ変態させ、これによって交換結合磁界を生じさせることができる。

【００１０】しかしながら前記反強磁性層と強磁性層との界面で、反強磁性層を構成する反強磁性材料の原子と、固定磁性層を構成する軟磁性材料の原子とが１対１に対応する、いわゆる整合状態になっていると、前記反強磁性層は上記した規則変態を適切に起せず、大きな交換結合磁界は生じ得ないことがわかった。

【００１１】本発明は上記従来の課題を解決するためのものであり、反強磁性層として、元素Ｘ（Ｘは白金族元素）とＭｎとを含有する反強磁性材料を用いた場合、大きい交換異方性磁界を発生することができるようにした交換結合膜、およびこの交換結合膜を用いた磁気抵抗効果素子、ならびに前記磁気抵抗効果素子を用いた薄膜磁気ヘッドに関する。

【００１２】

【課題を解決するための手段】本発明は、反強磁性層と強磁性層とが接して形成され、前記反強磁性層と強磁性層との界面に交換結合磁界が発生し、前記強磁性層の磁化方向が一定方向にされる交換結合膜において、前記反強磁性層は、元素Ｘ（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうち１種または２種以上の元素である）とＭｎとを含有する反強磁性材料で形成され、前記交換結合膜を膜厚方向と平行な切断面に現われる前記反強磁性層に形成された結晶粒界と、強磁性層に形成された結晶粒界とが前記界面の少なくとも一部で不連続であることを特徴とするものである。

【００１３】ここで本発明で言う前記結晶粒界とは、２つの結晶粒が異なる結晶方位を保って前記それぞれの結晶粒が接する境界であり、２つの結晶粒の間で、原子配列が鏡面対称となる境界（いわゆる双晶境界）を含む。ここで「金属材料の物理（日刊工業新聞社（１９９２年２月２８日発行））の第５８頁には「特殊粒界」の一例として双晶境界が挙げられており、一般的に結晶粒界には双晶境界が含まれることが明確にされている。

【0014】図26は本発明におけるスピンバルブ膜を膜厚方向と平行な方向から切断し、その切断面を透過電子顕微鏡（TEM）で観測した写真であり、その模式図が図28に示されている。

【0015】膜構成としては下から、Si基板／Al_2O_3／下地層：Ta（3nm）／シードレイヤ：$Ni_{80}Fe_{20}$／反強磁性層：$Pt_{54}Mn_{46}$（15nm）／固定磁性層[Co（1．5nm）／Ru（0．8nm）／Co（2．5nm）]／非磁性中間層：Cu（2．5nm）／フリー磁性層：[Co（1nm）／$Ni_{80}Fe_{20}$（3nm）]／バックド層：Cu（1．5nm）／Ta／Ta酸化膜、である。なお各層に記載した括弧書き中の数値は膜厚を示している。またシードレイヤ、反強磁性層、フリー磁性層の組成比はat％である。

【0016】前記反強磁性層、および固定磁性層の成膜は、DCマグネトロンスパッタ装置で行い、前記2層の成膜の際に使用されるArガスのガス圧を3mTorrとした。また前記反強磁性層を成膜するとき、基板とターゲット間の距離を80mmとした。

【0017】上記した膜構成を有するスピンバルブ膜を成膜後、熱処理を施した。この時の熱処理温度は例えば200℃以上で時間は2時間以上である。なお熱処理真空度を10^{-7}Torrとした。図26に示す透過電子顕微鏡写真は、上記の熱処理後の状態を示したものである。

【0018】図26からわかるように、PtMn（反強磁性層）よりも上側に形成された各層には、隣接する層との界面が全く見えず、単一層のような状態になっている。これは前記PtMn合金膜よりも上側に形成された各層はそれぞれが原子番号の近い元素で構成されており、なおかつ結晶方位が各層で揃っているために、電子線の吸収や回折特性が似通り、透過電子顕微鏡像中で各層のコントラストに差を生じ難いことによると考えられる。

【0019】一方図26に示すように、PtMn合金膜と前記PtMn合金膜よりも上側に形成された層との界面は、明確に見てとれる。

【0020】そして透過電子顕微鏡写真には、前記PtMn合金膜に形成された結晶粒界と、PtMn合金膜よりも上側に形成された層に現れる結晶粒界も写真にはっきりと映し出されている。前記結晶粒界は膜厚方向に延びて形成されるものが多い。

【0021】ここで図28の模式図を参照すると、本発明におけるスピンバルブ膜では、例えば前記PtMn合金に形成された結晶粒界（5）と、前記PtMn合金膜よりも上側の各層に形成された結晶粒界（1）（2）（3）とは、PtMn合金膜と、その上の層との界面で不連続になっていることがわかる。

【0022】ここで前記結晶粒界（1）（2）（3）及び（5）は、2つの結晶粒が異なる結晶方位を保って前記それぞれの結晶粒が接する境界であると考えられる。一方、結晶粒界（4）（8）（9）（10）および（11）は、1つの結晶粒内で、原子配列が鏡面対称となる双晶境界であると考えられる。それぞれの前記双晶境界は平行して現れやすい。

【0023】前記結晶粒界（4）（8）（9）（10）および（11）も、前記PtMn合金膜よりも上側の各層に形成された結晶粒界（1）（2）（3）と界面で不連続状態となっていることがわかる。

【0024】このように反強磁性層に形成された結晶粒界と強磁性層に形成された結晶粒界とが界面で不連続になる原因については、後で考察することにするが、図26の透過電子顕微鏡写真が得られたスピンバルブ型薄膜素子であると、交換結合磁界は非常に大きくなり、10．9×10^4（A／m）程度の交換結合磁界が得られた。

【0025】次に図27は従来におけるスピンバルブ膜を膜厚方向と平行な方向から切断し、その切断面を透過電子顕微鏡（TEM）で観測した写真であり、その模式図が図29に示されている。

【0026】膜構成としては下から、Si基板／Al_2O_3／下地層：Ta（3nm）／シードレイヤ：$Ni_{80}Fe_{20}$（2nm）／反強磁性層：$Pt_{44}Mn_{56}$（13nm）／固定磁性層[Co（1．5nm）／Ru（0．8nm）／Co（2．5nm）]／非磁性中間層：Cu（2．5nm）／フリー磁性層：[Co（1nm）／$Ni_{80}Fe_{20}$（3nm）]／バックド層：Cu（1．5nm）／Ta／Ta酸化膜、である。なお各層に記載した括弧書き中の数値は膜厚を示している。またシードレイヤ、反強磁性層、フリー磁性層の組成比はat％である。

【0027】上記した本発明におけるスピンバルブ膜の膜構成との違いは、PtMn合金膜（反強磁性層）のPt量及び膜厚、さらには成膜条件などである。

【0028】前記反強磁性層、および固定磁性層の成膜は、DCマグネトロンスパッタ装置で行い、前記2層の成膜の際に使用されるArガスのガス圧を0．8mTorrとした。また前記反強磁性層を成膜するとき、基板とターゲット間の距離を50mmとした。

【0029】上記した膜構成を有するスピンバルブ膜を成膜後、熱処理を施した。この時の熱処理温度は例えば200℃以上で時間は2時間以上である。なお熱処理真空度を10^{-7}Torrとした。図27に示す透過電子顕微鏡写真は、上記の熱処理後の状態を示したものである。

【0030】図27からわかるように、膜厚方向にPtMn合金膜と前記PtMn合金膜の上に形成された各層とを貫く大きな結晶粒の塊が生じていることがわかる。

【0031】図29の模式図を参照すると、PtMn合金膜と前記PtMn合金膜よりも上側に形成された層に

は、界面を貫いて結晶粒界（６）（７）が形成されている。すなわち比較例のスピンバルブ膜においては、ＰｔＭｎ合金膜に形成される結晶粒界と前記ＰｔＭｎ合金膜よりも上側の層に形成される結晶粒界とが、前記界面で連続した状態となっているのである。

【００３２】なお前記結晶粒界（６）（７）は、２つの結晶粒が異なる結晶方位を保って前記それぞれの結晶粒が接する境界であると考えられ、前記反強磁性層には双晶境界は形成されていないものと考えられる。

【００３３】図２７に示す透過電子顕微鏡写真を有するスピンバルブ型薄膜素子では、交換結合磁界が非常に低く、０．２４×１０^4（Ａ／ｍ）程度の交換結合磁界しか得られなかった。

【００３４】以上のように本発明と従来とでは、反強磁性層と強磁性層との界面における、前記反強磁性層に形成された結晶粒界と、強磁性層に形成された結晶粒界との位置が異なるのである。

【００３５】本発明のように、反強磁性層に形成された結晶粒界と強磁性層に形成された結晶粒界とを界面で不連続にするには、一つは前記反強磁性層の組成が重要であり、その他に成膜条件が重要である。成膜条件とは熱処理温度や熱処理時間、および前記反強磁性層、強磁性層を成膜する際のＡｒガス圧、さらには基板とターゲット間の距離、基板温度、基板バイアス電圧、成膜速度などである。

【００３６】一方、本発明と異なる反強磁性層の組成や成膜条件で前記反強磁性層を成膜すると、図２９で見た比較例のように、反強磁性層に形成された結晶粒界と強磁性層に形成された結晶粒界とが界面で連続した状態にしやすい。

【００３７】界面での結晶粒界が不連続とされた本発明では、成膜段階において、反強磁性層と強磁性層とはエピタキシャル的に成長せず、前記反強磁性層を構成する原子は強磁性層の結晶構造に強固に拘束されていないと考えられる。このため熱処理を施したとき、前記反強磁性層は不規則格子から規則格子へ適切に変態し大きな交換結合磁界を得ることができる。

【００３８】一方、界面での結晶粒界が連続とされた比較例の場合、成膜段階において、反強磁性層と強磁性層とはエピタキシャル的に成長し、前記反強磁性層の原子は強磁性層の結晶構造に強固に拘束された状態になっていると考えられる。このため熱処理を施しても、前記反強磁性層は不規則格子から規則格子へ適切に変態できず、交換結合磁界は非常に小さくなってしまう。

【００３９】なお本発明では前記反強磁性層の結晶粒界と強磁性層の結晶粒界は、前記界面の少なくとも一部において不連続な状態となっていればよい。

【００４０】また前記反強磁性層と強磁性層の結晶配向は、膜面と平行な方向に異なる結晶面が優先配向するものでもよいが、好ましくは同じ等価な結晶面が優先配向

するものであることが好ましい。

【００４１】具体的には本発明では、前記反強磁性層及び強磁性層は、前記界面と平行な方向に［１１１］面として表される等価な結晶面が優先配向していることが好ましい。前記［１１１］面とは、ミラー指数を用いて表した単結晶構造の場合における等価な結晶面の総称であり、前記等価な結晶面には（１１１）面、（-１１１）面、（1-１１）面、（１１-1）面、（-1-１１）面、（１-1-1）面、（-１１-1）面、（-1-1-1）面が存在する。

【００４２】なお図２６と図２７に示す透過電子顕微鏡写真を有するスピンバルブ型薄膜素子では、共に膜面と平行な方向に［１１１］面の格子縞が見られ、反強磁性層と前記反強磁性層よりも上側に形成された層は、本発明及び比較例ともに、膜面と平行な方向に［１１１］面と等価な結晶面が優先配向していると認められた。

【００４３】このように同じ等価な結晶面が反強磁性層と強磁性層とで優先配向している場合には、大きな抵抗変化率（ΔＲ／Ｒ）を得ることが可能である。

【００４４】また本発明は、反強磁性層と強磁性層とが接して形成され、前記反強磁性層と強磁性層との界面に交換結合磁界が発生し、前記強磁性層の磁化方向が一定方向にされる交換結合膜において、前記反強磁性層は前記界面と平行な方向に［１１１］面として表される等価な結晶面が優先配向し、前記反強磁性層には少なくとも一部に双晶が形成され、少なくとも一部の前記双晶の双晶境界は、前記界面と非平行に形成されていることを特徴とするものである。

【００４５】この発明では、反強磁性層は、前記界面と平行な方向に［１１１］面として表される等価な結晶面が優先配向している。なお前記反強磁性層を［１１１］面配向させるには前記反強磁性層の下側にシードレイヤを敷くことが効果的である。

【００４６】本発明では、反強磁性層に形成された少なくとも一部の双晶の双晶境界は前記界面と非平行に形成されているが、それは図２６および図２８を見れば明らかである。

【００４７】すなわち図２６および図２８に示すように、反強磁性層には、双晶が形成され、前記双晶内には、双晶境界を示す粒界（４）（８）（９）（１０）及び（１１）が現れている。そしてこれら双晶境界はいずれも界面と非平行になっている。

【００４８】またここで、図２６に示す膜構成とは違う膜構成のものを膜厚と平行な方向から切断し、その切断面を透過電子顕微鏡（ＴＥＭ）で観測した写真を図３０に示す。

【００４９】膜構成は下から、Ｓｉ基板／Al_2O_3／下地層：Ｔａ（３ｎｍ）／シードレイヤ：$Ni_{80}Fe_{20}$（２ｎｍ）／反強磁性層：$Pt_{49}Mn_{51}$（１６ｎｍ）／固定磁性層［$Co_{90}Fe_{10}$（１．４ｎｍ）／Ｒｕ

（０．９ｎｍ）／$Co_{90}Fe_{10}$（２．２ｎｍ）］／非磁性中間層：Ｃｕ（２．２ｎｍ）／フリー磁性層：［$Co_{90}Fe_{10}$（１ｎｍ）／$Ni_{80}Fe_{20}$（４ｎｍ）］／Ｔａ（３ｎｍ）である。なお括弧内の数値は膜厚を示している。なお反強磁性層、固定磁性層及びフリー磁性層の組成比はａｔ％である。

【００５０】前記反強磁性層、および固定磁性層の成膜は、ＤＣマグネトロンスパッタ装置で行い、前記２層の成膜の際に使用されるＡｒガスのガス圧を２．５ｍＴｏｒｒとした。また前記反強磁性層を成膜するとき、基板とターゲット間の距離を８０ｍｍとした。

【００５１】上記した膜構成を有するスピンバルブ膜を成膜後、熱処理を施した。この時の熱処理温度は例えば２７０℃で時間は４時間であった。また熱処理真空度を10^{-7}Ｔｏｒｒとした。なおこの実施例では図２６のものとＰｔＭｎの組成比や膜厚、成膜条件などが異なる。

【００５２】図３０に示す透過電子顕微鏡写真は、上記の熱処理後の状態を示したものである。また反強磁性層及び強磁性層は、界面と平行な方向に等価な[１１１]面が優先配向していることが、電子線回折像によりわかった。

【００５３】図３１は、図３０に示すＴＥＭ写真の模式図である。図３１に示すように、反強磁性層には、複数の双晶境界が形成され、これら双晶境界はいずれも強磁性層との界面と非平行であることがわかる。

【００５４】一方、既に説明したように図２７および図２９に示す比較例では、反強磁性層に双晶が形成されておらず、よって双晶境界は現れていないことがわかる。

【００５５】本発明のように、反強磁性層に双晶が形成され、前記双晶内に双晶境界が前記界面と非平行に形成されている場合、前記反強磁性層は熱処理によって適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。図３０に示す膜構成での交換結合磁界は、約9.3×10^{4}（Ａ／ｍ）であった。

【００５６】ところで前記双晶境界は成膜段階において形成されているか否かは重要ではない。成膜段階で前記双晶境界が形成されていなくても熱処理を施すことによって本発明のような前記双晶境界が現れることがある。

【００５７】本発明では、成膜段階において前記反強磁性層の原子は強磁性層の結晶構造に拘束された状態にないと思われる。このように界面での拘束力が弱くなると、前記反強磁性層は熱処理によって不規則格子から規則格子に変態しやすくなるが、前記変態の際には格子歪が発生するため、この格子歪を適切に緩和できないと、前記変態を効果的に起すことはできない。変態をするときには反強磁性層の原子が不規則格子から規則格子への再配列を起し、このとき生じる格子歪を、短い距離間隔で原子配列が鏡面対称に変化していくことで緩和していくものと考えられる。熱処理後、前記鏡面対称変化の境

は双晶境界となり、このような双晶境界が形成されていることは、いわば熱処理を施したときに規則化変態が起こっていることを意味する。

【００５８】ここで反強磁性層と強磁性層との界面付近では、前記界面と平行な方向に原子が再配列するときに生じる格子歪を緩和するため、前記界面と交わる方向に前記双晶境界が形成される。このため全体的に適切な規則化変態が起きたとき前記双晶境界は前記界面と非平行に形成される。これが本発明であり、本発明のように界面と非平行に双晶境界が形成された場合、非常に大きな交換結合磁界を得ることが可能になる。一方、前記界面と平行な方向に原子が再配列できないとき、すなわち界面において前記反強磁性層の原子が強磁性層の結晶構造に強固に拘束されているときなどは、前記界面と交わるように双晶境界は形成されない。かかる場合、前記双晶境界は形成されなかったり、あるいは前記界面と平行な双晶境界が形成されたりするのである。

【００５９】なお前記双晶境界は、図２６や図３０のように同じ双晶内に複数形成されるとき、それぞれの双晶境界どうしはほぼ平行となる。

【００６０】なお図３０に示す実施例の反強磁性層及び強磁性層には共に特別な対称関係を持たない粒界が形成されており、反強磁性層側に形成された前記粒界及び双晶境界は、強磁性層に形成された粒界とは界面で不連続な状態であることがわかる。

【００６１】また本発明では、前記双晶境界と前記界面間の内角は、６８°以上で７６°以下であることが好ましい。この範囲内であると前記反強磁性層は界面と平行な方向に等価な[１１１]面が優先配向する。

【００６２】また本発明では、前記強磁性層は、前記界面と平行な方向に[１１１]面として表される等価な結晶面が優先配向していることが好ましい。

【００６３】本発明のように前記反強磁性層及び強磁性層が共に界面と平行な方向に[１１１]面として表される等価な結晶面が優先配向していると、大きな抵抗変化率を得ることが可能である。

【００６４】また本発明では、前記反強磁性層は、元素Ｘ（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうち１種または２種以上の元素である）とＭｎとを含有する反強磁性材料で形成されることが好ましい。

【００６５】また本発明では、上記のように反強磁性層と強磁性層の膜面と平行な方向における結晶配向が[１１１]面として表される等価な結晶面となるように、前記反強磁性層の下側にシードレイヤを形成したのである。

【００６６】本発明では、前記交換結合膜は、下から反強磁性層、強磁性層の順に積層され、さらに前記反強磁性層の下側に、結晶構造が主として面心立方晶から成り、しかも前記界面と平行な方向に[１１１]面として表される等価な結晶面が優先配向したシードレイヤが形成

されていることが好ましい。

【0067】このように本発明では反強磁性層の下側にシードレイヤを設けることで、前記反強磁性層及び強磁性層は膜面と平行な方向に、代表的に[１１１]面として表される等価な結晶面が優先配向する。

【0068】また本発明では、前記シードレイヤは、ＮｉＦｅ合金、ＮｉあるいはＮｉ－Ｆｅ－Ｙ合金（ただしＹは、Ｃｒ，Ｒｈ，Ｔａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉから選ばれる少なくとも１種以上）、さらにはＮｉ－Ｙ合金で形成されることが好ましい。

【0069】また前記シードレイヤは、組成式が $(\mathrm{Ni}_{1-x}\mathrm{Fe}_x)_{1-y}\mathrm{Y}_y$（ｘ，ｙは原子比率）で示され、原子比率ｘは０以上で０．３以下で、原子比率ｙは０以上で０．５以下であることが好ましい。また前記シードレイヤは常温で非磁性であることが好ましい。

【0070】また本発明では、前記シードレイヤの下には、Ｔａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉ，Ｍｏ，Ｗのうち少なくとも１種以上の元素で形成された下地層が形成されていることが好ましい。

【0071】さらに本発明では、前記反強磁性層とシードレイヤとの界面の少なくとも一部は非整合状態であることが好ましい。ここで非整合状態とは、反強磁性層を構成する原子と強磁性層（シードレイヤ、なお室温では非磁性）を構成する原子とが界面で１対１に対応しない状態のことを指す。一方、整合状態とは前記界面で原子が１対１で対応する状態のことを指す。

【0072】ところで本発明では、上記したように反強磁性層に形成された結晶粒界と強磁性層に形成された結晶粒界とが界面の少なくとも一部で不連続な状態となっているが、この結晶構造は前記反強磁性層とシードレイヤとの界面においても生じていることが好ましい。

【0073】すなわち本発明では、反強磁性層に形成された結晶粒界とシードレイヤに形成された結晶粒界が界面の少なくとも一部で不連続な状態となっていることが好ましい。これによって前記反強磁性層は熱処理を施したときに、前記シードレイヤの結晶構造に拘束されずに適切な規則変態を起しており、大きな交換結合磁界を得ることが可能になる。

【0074】また本発明では、前記反強磁性層は、Ｘ－Ｍｎ－Ｘ′合金（ただし元素Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成されていてもよい。この場合、前記Ｘ―Ｍｎ―Ｘ′合金は、元素ＸとＭｎとで構成される空間格子の隙間に元素Ｘ′が侵入した侵入型固溶体であり、あるいは、元素ＸとＭｎとで構成される結晶格子の格子点の一部が、元素Ｘ′に置換された置換型固溶体であることが好ましい。これによって反強磁性層の格子定数を広げることができ、強磁性層との界面において、前記強磁性層の原子配列に対して１対１に対応しない原子配列を形成することが可能である。

【0075】また本発明では、前記元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は、４５（ａｔ％）以上６０（ａｔ％）以下であることが好ましい。後述する実験結果により、前記元素Ｘあるいは元素Ｘ＋Ｘ′の組成比が上記範囲内であると少なくとも１．５８×１０^4（Ａ／ｍ）以上の交換結合磁界を得ることができる。なおより好ましくは、前記元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は、４９（ａｔ％）以上５６．５（ａｔ％）以下である。

【0076】また本発明では、前記反強磁性層と強磁性層との界面の少なくとも一部は非整合状態であることが好ましい。

【0077】本発明では、上記した交換結合膜を様々な磁気抵抗効果素子に適用することができる。

【0078】本発明は、反強磁性層と、この反強磁性層と接して形成され、前記反強磁性層との交換異方性磁界により磁化方向が固定される固定磁性層と、前記固定磁性層に非磁性中間層を介して形成されたフリー磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向へ揃えるバイアス層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、上記した交換結合膜により形成されていることを特徴とするものである。

【0079】また本発明は、反強磁性層と、この反強磁性層と接して形成され、前記反強磁性層との交換異方性磁界により磁化方向が固定される固定磁性層と、前記固定磁性層に非磁性中間層を介して形成されたフリー磁性層とを有し、前記フリー磁性層の上側または下側に、トラック幅Ｔｗの間隔を空けて反強磁性のエクスチェンジバイアス層が形成され、前記エクスチェンジバイアス層とフリー磁性層とが、上記した交換結合膜により形成され、前記フリー磁性層の磁化が一定方向にされることを特徴とするものである。

【0080】また本発明は、フリー磁性層の上下に積層された非磁性中間層と、一方の前記非磁性中間層の上および他方の非磁性中間層の下に位置する固定磁性層と、一方の前記固定磁性層の上および他方の固定磁性層の下に位置して、交換異方性磁界によりそれぞれの固定磁性層の磁化方向を一定の方向に固定する反強磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向に揃えるバイアス層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、上記した交換結合膜により形成されていることを特徴とするものである。

【0081】また本発明は、非磁性層を介して重ねられた磁気抵抗層と軟磁性層とを有し、前記磁気抵抗層の上側あるいは下側にトラック幅Ｔｗの間隔を空けて反強磁

性層が形成され、前記反強磁性層と磁気抵抗層とが、上記した交換結合膜により形成されていることを特徴とするものである。

【００８２】また本発明における薄膜磁気ヘッドは、上記した磁気抵抗効果素子の上下にギャップ層を介してシールド層が形成されていることを特徴とするものである。

【００８３】

【発明の実施の形態】図１は本発明の第１実施形態のシングルスピンバルブ型磁気抵抗効果素子の全体構造をＡＢＳ面側から見た断面図である。なお、図１ではＸ方向に延びる素子の中央部分のみを破断して示している。

【００８４】このシングルスピンバルブ型磁気抵抗効果素子は、ハードディスク装置に設けられた浮上式スライダのトレーリング側端部などに設けられて、ハードディスクなどの記録磁界を検出するものである。なお、ハードディスクなどの磁気記録媒体の移動方向はＺ方向であり、磁気記録媒体からの洩れ磁界の方向はＹ方向である。

【００８５】図1の最も下に形成されているのはＴａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉ，Ｍｏ，Ｗのうち１種または２種以上の元素などの非磁性材料で形成された下地層６である。前記下地層６は、その上に形成されるシードレイヤ２２の｛１１１｝面として表される等価な結晶面を、膜面と平行な方向に優先配向させるために設けられたものである。前記下地層６は例えば５０Å程度の膜厚で形成される。

【００８６】前記シードレイヤ２２は、主として面心立方晶から成り、前記反強磁性層４との界面と平行な方向に、代表的に｛１１１｝面として表される等価な結晶面が優先配向されている。前記シードレイヤ２２は、ＮｉＦｅ合金、ＮｉあるいはＮｉ－Ｆｅ－Ｙ合金（ただしＹは、Ｃｒ，Ｒｈ，Ｔａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉから選ばれる少なくとも１種または２種以上）、Ｎｉ－Ｙ合金で形成されることが好ましい。

【００８７】なお前記シードレイヤ２２は、組成式が$(Ni_{1-x}Fe_x)_{1-y}Y_y$（ｘ，ｙは原子比率）で示され、原子比率ｘは０以上で０．３以下で、原子比率ｙは０以上で０．５以下であることが好ましい。これによって反強磁性層４及びその上の各層の［１１１］面の優先配向度を高めることができ、抵抗変化率ΔＲ／Ｒを高めることができる。

【００８８】ここで「等価な結晶面」とは、ミラー指数を用いて表した結晶格子面を示し、前記［１１１］面として表される等価（同等）な結晶面としては（１１１）面、（－１１１）面、（１－１１）面、（１１－１）面、（－１－１１）面、（１－１－１）面、（－１１－１）面、（－１－１－１）面が存在する。

【００８９】すなわち本発明では、前記シードレイヤ２２は（１１１）面や、それと等価な（１－１１）面等が膜面と平行な方向に優先配向しているのである。

【００９０】また本発明では前記シードレイヤ２２は常温にて非磁性であることが好ましい。前記シードレイヤ２２を常温で非磁性とすることにより、波形の非対称性（アシンメトリー）の悪化を防ぐことができるとともに、非磁性にするために添加する元素Ｙ（後述）の効果により、前記シードレイヤ２２の比抵抗を大きくすることができ、導電層から流れるセンス電流の前記シードレイヤ２２への分流を抑制することが可能である。前記センス電流がシードレイヤ２２に分流しやすくなると、抵抗変化率（ΔＲ／Ｒ）の低下やバルクハウゼンノイズの発生に繋がり好ましくない。

【００９１】前記シードレイヤ２２を非磁性で形成するには、上記した材質のうちＮｉ－Ｆｅ－Ｙ合金（ただしＹは、Ｃｒ，Ｒｈ，Ｔａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉから選ばれる少なくとも１種または２種以上）やＮｉ－Ｙ合金を選択できる。これら材質は、結晶構造が面心立方晶であり、しかも膜面と平行な方向に、代表的に［１１１］面として表される等価な結晶面が優先配向しやすく好ましい。前記シードレイヤ２２は、例えば３０Å程度で形成される。

【００９２】前記シードレイヤ２２の上には反強磁性層４が形成される。前記反強磁性層４は、元素Ｘ（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうち１種または２種以上の元素である）とＭｎとを含有する反強磁性材料で形成されることが好ましい。

【００９３】これら白金族元素を用いたＸ－Ｍｎ合金は、耐食性に優れ、またブロッキング温度も高く、さらに交換結合磁界（Ｈｅｘ）を大きくできるなど反強磁性材料として優れた特性を有する。特に白金族元素のうちＰｔを用いることが好ましい。例えば二元系で形成されたＰｔＭｎ合金を使用することができる。

【００９４】また本発明では、前記反強磁性層４を元素Ｘと元素Ｘ′（ただし元素Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）とＭｎとを含有する反強磁性材料で形成してもよい。

【００９５】なお前記元素Ｘ′には、元素ＸとＭｎとで構成される空間格子の隙間に侵入し、または元素ＸとＭｎとで構成される結晶格子の格子点の一部と置換する元素を用いることが好ましい。ここで固溶体とは、一つの結晶相内において、均一に成分が混ざり合った固体のことを指している。

【００９６】侵入型固溶体あるいは置換型固溶体とすることで、前記Ｘ－Ｍｎ合金膜の格子定数に比べて、前記Ｘ－Ｍｎ－Ｘ′合金の格子定数を大きくすることができるので、後述する固定磁性層３の格子定数との差を広げ

ることができ、前記反強磁性層４と固定磁性層３との界面構造を非整合状態にしやすくできる。また特に置換型で固溶する元素X′を使用する場合は、前記元素X′の組成比が大きくなりすぎると、反強磁性としての特性が低下し、固定磁性層３との界面で発生する交換結合磁界が小さくなってしまう。特に本発明では、侵入型で固溶し、不活性ガスの希ガス元素（Ｎｅ，Ａｒ，Ｋｒ，Ｘｅのうち１種または２種以上）を元素X′として使用することが好ましいとしている。希ガス元素は不活性ガスなので、希ガス元素が、膜中に含有されても、反強磁性特性に大きく影響を与えることがなく、さらに、Ａｒなどは、スパッタガスとして従来からスパッタ装置内に導入されるガスであり、ガス圧を適正に調節するのみで、容易に、膜中にＡｒを侵入させることができる。

【００９７】なお、元素X′にガス系の元素を使用した場合には、膜中に多量の元素X′を含有することは困難であるが、希ガスの場合においては、膜中に微量侵入させるだけで、熱処理によって発生する交換結合磁界を、飛躍的に大きくできる。

【００９８】なお本発明では、好ましい前記元素X′の組成範囲は、ａｔ％で０．２から１０であり、より好ましくは、ａｔ％で、０．５から５である。また本発明では前記元素ＸはＰｔであることが好ましく、よってＰｔ－Ｍｎ－X′合金を使用することが好ましい。

【００９９】次に前記反強磁性層４の上には３層膜で形成された固定磁性層３が形成されている。

【０１００】前記固定磁性層３は、Ｃｏ膜１１とＲｕ膜１２とＣｏ膜１３とで形成され、前記反強磁性層４との界面での交換結合磁界及び前記Ｃｏ膜１１とＣｏ膜１３の間にＲｕ膜１２を介して働くＲＫＫＹ的反強磁性結合により前記Ｃｏ膜１１とＣｏ膜１３の磁化方向は互いに反平行状態にされる。これは、いわゆるフェリ磁性結合状態と呼ばれ、この構成により固定磁性層３の磁化を安定した状態にでき、また前記固定磁性層３と反強磁性層４との界面で発生する交換結合磁界を大きくすることができる。

【０１０１】なお前記Ｃｏ膜１１は例えば２０Å程度で形成され、Ｒｕ膜１２は８Å程度で形成され、Ｃｏ膜１３は１５Å程度で形成される。

【０１０２】なお前記固定磁性層３は３層膜で形成されなくても良く、例えば単層膜で形成されてもよい。また各層１１，１２，１３は、上記した磁性材料以外の材料によって形成してもよい。例えば前記層１１や１３には、ＣｏのほかにＣｏＦｅなどを選択できる。

【０１０３】前記固定磁性層３の上には非磁性中間層２が形成されている。前記非磁性中間層２は、例えばＣｕで形成されている。なお本発明における磁気抵抗効果素子が、トンネル効果の原理を用いたトンネル型磁気抵抗効果素子（ＴＭＲ素子）の場合、前記非磁性中間層２は、例えばAl_2O_3等の絶縁材料で形成される。

【０１０４】さらに前記非磁性中間層２の上には２層膜で形成されたフリー磁性層１が形成される。

【０１０５】前記フリー磁性層１は、ＮｉＦｅ合金膜９とＣｏ膜１０の２層で形成される。図１に示すように前記Ｃｏ膜１０を非磁性中間層２と接する側に形成することにより、前記非磁性中間層２との界面での金属元素等の拡散を防止し、ΔＲ／Ｒ（抵抗変化率）を大きくすることができる。

【０１０６】なお前記ＮｉＦｅ合金膜９は、例えば前記Ｎｉを８０（ａｔ％）、Ｆｅを２０（ａｔ％）として形成する。また前記ＮｉＦｅ合金膜９の膜厚を例えば４５Å程度、Ｃｏ膜を５Å程度で形成する。

【０１０７】図１に示すように前記フリー磁性層１の上にはＴａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉ，Ｍｏ，Ｗのうち１種または２種以上の元素などの非磁性材料で形成された保護層７が形成されている。

【０１０８】さらに前記下地層６から保護層７までの積層膜の両側にはハードバイアス層５及び導電層８が形成されている。前記ハードバイアス層５からのバイアス磁界によってフリー磁性層１の磁化はトラック幅方向（図示Ｘ方向）に揃えられる。

【０１０９】前記ハードバイアス層５，５は、例えばＣｏ－Ｐｔ（コバルト－白金）合金やＣｏ－Ｃｒ－Ｐｔ（コバルト－クロム－白金）合金などで形成されており、導電層８，８は、α－Ｔａ、Ａｕ、Ｃｒ、Ｃｕ（銅）やＷ（タングステン）などで形成されている。なお上記したトンネル型磁気抵抗効果素子の場合、前記導電層８，８は、フリー磁性層１の下側と、反強磁性層４の上側にそれぞれ形成されることになる。

【０１１０】また本発明では、上記したフリー磁性層１の上に、金属材料あるいは非磁性金属のＣｕ，Ａｕ，Ａｇからなるバックド層が形成されていてもよい。例えば前記バックド層の膜厚は１２～２０Å程度で形成される。

【０１１１】また前記保護層７には、Ｔａなどから成りその表面が酸化された酸化層が形成されていることが好ましい。

【０１１２】前記バックド層が形成されることによって、磁気抵抗効果に寄与する＋スピン（上向きスピン：ｕｐ　ｓｐｉｎ）の電子における平均自由工程（ｍｅａｎ　ｆｒｅｅ　ｐａｔｈ）を延ばし、いわゆるスピンフィルター効果（ｓｐｉｎ　ｆｉｌｔｅｒ　ｅｆｆｅｃｔ）によりスピンバルブ型磁気素子において、大きな抵抗変化率が得られ、高記録密度化に対応できるものとなる。

【０１１３】上記した各層を積層した後、本発明では熱処理を施して反強磁性層４と固定磁性層３との界面に交換結合磁界（Ｈｅｘ）を発生させ、これにより前記固定磁性層３の磁化をハイト方向（図示Ｙ方向）に固定するが、熱処理後における前記スピンバルブ型薄膜素子で

は、以下のような結晶配向を有している。

【０１１４】前記結晶配向については、主に反強磁性層と強磁性層（固定磁性層）とで形成される交換結合膜を中心して説明する。

【０１１５】本発明では上記したように、反強磁性層４の下側にシードレイヤ２２が形成されている。前記シードレイヤ２２は、代表的に[１１１]面として表される等価な結晶面が膜面に優先配向するように形成されているが、これによって前記シードレイヤ２２上に形成される反強磁性層４もまた膜面と平行な方向に、前記シードレイヤ２２と同じ結晶面が膜面と平行方向に優先配向される。

【０１１６】例えばシードレイヤ２２は、膜面と平行な方向に（－１１１）面が優先配向する場合、前記シードレイヤ２２上に形成される反強磁性層４も膜面と平行な方向に（－１１１）面が優先配向する。

【０１１７】さらに前記反強磁性層４の上に形成される固定磁性層３もまた前記反強磁性層４と同じ等価な結晶面が膜面と平行な方向に優先配向する。

【０１１８】すなわち本発明では、シードレイヤ２２、反強磁性層４及び固定磁性層３は、膜面と平行な方向に、代表的に｛１１１｝面として表される同じ等価な結晶面が優先配向しているのである。

【０１１９】なお本発明では、前記膜面と平行な方向に優先配向する結晶面は、代表的に[１１１]面として表される等価な結晶面であることが好ましいが、これは前記結晶面が最密面であるからである。例えば磁気ヘッド装置内の環境温度やセンス電流密度が高くなると、特に熱的な安定性が求められるが、膜面と平行な方向に最密面である[１１１]面として表される等価な結晶面が優先配向すると膜厚方向の原子の拡散が起こり難く、多層膜界面の熱的安定性が増し、特性の安定化を図ることが可能である。

【０１２０】本発明ではこのように反強磁性層４及び固定磁性層３は、膜面と平行な方向に同じ等価な結晶面が優先配向するが、さらに本発明では、前記結晶面内に存在する、ある同じ結晶軸の少なくとも一部が、前記反強磁性層４及び固定磁性層３とで互いに異なる方向を向いているのである（図１４参照）。なお図１４では、例えば（１１１）面内に存在する［１１０］方向が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いていることがわかる。

【０１２１】このような結晶配向を生じる原因としては、前記反強磁性層４と固定磁性層３とを成膜段階（熱処理前）において、如何なる状態で成膜したかに依存すると考えられる。

【０１２２】例えば反強磁性層４の材質及び組成比を調整し、さらに成膜条件等を制御し前記反強磁性層４の格子定数を固定磁性層３の格子定数よりも充分に大きくした状態で各層を成膜すると、前記反強磁性層４及び固定

磁性層３は、エピタキシャル的な成長をしづらいものと考えられる。

【０１２３】エピタキシャル的に成膜されると、反強磁性層４と固定磁性層３とで全ての結晶方位が平行関係を有して成膜されやすい。そして前記反強磁性層４と固定磁性層３との界面では、前記界面と平行な方向に同じ等価な結晶面が優先配向するのみならず、前記結晶面内に存在する、反強磁性層４と固定磁性層３とのある同一の等価な結晶軸が同じ方向に向き、前記界面で反強磁性層４の原子の配列と固定磁性層３の原子の配列とが１対１に対応しやすくなる（図１５参照）。なお図１５には具体的な例として、（１１１）面内に存在する［１１０］方向が、反強磁性層３１と強磁性層３０とで同じ方向を向いていることが示されている。

【０１２４】このような結晶配向が熱処理前の段階で生じていると、前記反強磁性層４は熱処理を施しても固定磁性層３の結晶構造に拘束されて、適切な規則変態を起せず、交換結合磁界は非常に低下してしまう。

【０１２５】本発明では、上記のようなエピタキシャル的な成長をせずに、反強磁性層４と固定磁性層３とが成膜されたものと考えられ、このような成膜状態で熱処理を施すと、前記反強磁性層４は固定磁性層３の結晶構造に拘束されず適切な規則変態を起す。熱処理後の本発明におけるスピンバルブ膜の膜構造を観測すると、前記反強磁性層４と固定磁性層３は、膜面と平行な方向に互いに同じ等価な結晶面が優先配向しながらも、前記膜面と平行な方向に配向しない他の結晶面では、前記反強磁性層４と固定磁性層３とで平行関係を保たず、この結果、前記膜面平行に配向した前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部は、反強磁性層４と固定磁性層３とで互いに異なる方向を向いているのである。

【０１２６】本発明では、上記した結晶配向を生じさせるための一つの方法として反強磁性層４の下側にシードレイヤ２２を敷いた。既に説明したように、シードレイヤ２２を設けることで前記シードレイヤ２２上に形成される反強磁性層４及び固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、このような結晶配向は、大きな抵抗変化率（ΔＲ／Ｒ）をもたらす。

【０１２７】また本発明では、前記反強磁性層４及び固定磁性層３の膜面平行な方向に配向する前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部は互いに異なる方向を向いているが、このような結晶方位の存在は、熱処理段階で前記反強磁性層４は固定磁性層３の結晶構造に拘束されずに、不規則相としての面心立方格子から規則相としてのＣｕＡｕ－Ｉ型の面心正方格子に適切に変態したものと考えられ、従来に比べて大きな交換結合磁界を得ることが可能である。なお本発明では、熱処理後において前記反強磁性層４の少なくとも一部の結晶構造がＣｕＡｕ－Ｉ型の面心正方規則格子とな

っていればよい。

【０１２８】また本発明では、以下のような結晶組織を有することが大きな交換結合磁界を得る上で重要である。

【０１２９】すなわち本発明では、前記切断面に現われる前記反強磁性層４の結晶粒界と、固定磁性層３の結晶粒界とが、前記反強磁性層４と固定磁性層３との界面の少なくとも一部で不連続な状態となっているのである。

【０１３０】なお本発明で言う前記結晶粒界とは、２つの結晶粒が異なる結晶方位を保って前記それぞれの結晶粒が接する境界であり、２つの結晶粒の間で、原子配列が鏡面対称となる境界（いわゆる双晶境界）を含む。図２８に示す粒界（１）（２）（３）及び（５）は、特別な対称関係を持たない前者の境界であり、図２８に示す粒界（４）（８）（９）（１０）及び（１１）は後者の双晶境界であると思われる。

【０１３１】図２６，２８（図２６は透過電子顕微鏡写真（ＴＥＭ写真）、図２８は図２６に示す写真の模式図）に示すように本発明では、ＰｔＭｎ合金膜（反強磁性層４）に形成された結晶粒界（４）（５）（８）（９）（１０）及び（１１）と、前記反強磁性層４上層に形成された結晶粒界（１）（２）（３）とが、前記界面で不連続な状態になっており、このような不連続状態が生じる場合には、前記界面において反強磁性層４の膜面方向の結晶面と、固定磁性層３の膜面方向の結晶面とに存在する、ある同じ等価な結晶軸の少なくとも一部が異なる方向を向いているものと推測できる。また別の実施例として挙げた図３０、３１においても、反強磁性層に形成された、特別な対称関係を持たない粒界と双晶境界は、強磁性層に形成された粒界と界面で不連続であることがわかる。

【０１３２】図２６，２８、３０、３１に示す結晶構造は、比較例として表される図２７，２９（図２７は透過電子顕微鏡写真（ＴＥＭ写真）、図２９は図２７に示す写真の模式図）に示す結晶組織とは明らかに異なることがわかる。図２７，２９では、ＰｔＭｎ合金膜（反強磁性層４）に形成された結晶粒界と、ＰｔＭｎ合金膜の上の層に形成された結晶粒界が界面で連続し、反強磁性層４からその上の層にかけて前記界面を貫く大きな結晶粒が形成されているからである。

【０１３３】本発明のように図２６，２８、３０、３１に示すような結晶粒界を有する交換結合膜であると、成膜段階において前記反強磁性層４と固定磁性層３とはエピタキシャル的な成長をせずに成膜されたものと考えられ、したがって熱処理によって前記反強磁性層４は固定磁性層３の結晶構造に拘束されずに適切な規則変態を起しており、大きな交換結合磁界を得ることができるのである。

【０１３４】また図２８に示す粒界（４）（８）（９）（１０）及び（１１）、すなわち双晶境界は、界面と非平行であることがわかる。同様に別の実施例としての図３０及び図３１に示した双晶境界も前記界面と非平行であることがわかる。なお本発明におけるいずれの実施例でも前記反強磁性層は、前記反強磁性層の下側にシードレイヤ層が敷かれているため前記界面と平行な方向に［１１１］面として表される等価な結晶面が優先配向している。

【０１３５】なお双晶とは、１つの物質の単結晶が２つ以上、互いに特定の対称関係に従って結合している一固体をいう。そして前記双晶には双晶境界が形成され、前記双晶境界を境にして原子配列が鏡面対称となっている。このような双晶が生じるのは、内部応力の緩和のためである。ちなみに双晶境界が形成されて内部応力の緩和が促進されても、ある部分で大きな内部応力が発生している場合には、もはや双晶境界では適切な内部応力の緩和を行えず、図２８の粒界（５）、図３０の粒界のような、２つの結晶粒が異なる結晶方位を保って前記それぞれの結晶粒が接する境界が形成されて、前記の大きな内部応力が緩和されていくものと考えられる。

【０１３６】本発明のように前記反強磁性層に形成された双晶境界が界面と非平行である場合には、前記界面において反強磁性層４の膜面方向の結晶面と、固定磁性層３の膜面方向の結晶面とに存在する、ある同じ等価な結晶軸の少なくとも一部が異なる方向を向いているものと推測できる。

【０１３７】前記反強磁性層４は成膜後、熱処理を施すことによって不規則格子から規則格子への変態が起こなければ大きな交換結合磁界を得ることはできないが、変態時、界面と平行な方向及び膜厚方向に原子が移動するときに生じる格子歪を緩和すべく、原子配列が鏡面対称に変化する双晶境界が形成される。そしてこのとき前記双晶境界は前記界面と非平行に形成される。

【０１３８】前記反強磁性層が不規則格子から規則格子に適切に変態すると、前記反強磁性層には前記界面と非平行になる双晶境界が形成され、大きな交換結合磁界が発生する。なおある双晶内には前記双晶境界は複数形成されていても良く、かかる場合、それぞれの前記双晶境界どうしはほぼ平行状態になる。

【０１３９】一方、比較例を示す図２７及び図２９では、前記反強磁性層に全く双晶境界が形成されていない。これはすなわち、熱処理を施しても前記反強磁性層の原子は変態時に起こる再配列が成されていないからであり、よって不規則格子から規則格子への変態がほとんど進行せず、小さな交換結合磁界しか得ることができない。

【０１４０】また前記反強磁性層に双晶境界が形成されても、前記双晶境界が前記界面と平行であるときには、膜厚方向への格子歪はある程度緩和されていると推測できるが、前記界面と平行な方向への原子再配列は全く起こっておらず、よって特に界面で前記反強磁性層は不規

則格子から規則格子に適切に変態していない。従って交換結合磁界は小さくなってしまう。

【０１４１】なお本発明では、前記双晶境界と前記界面間の内角θ（図２８及び図３１を参照のこと）は６８°以上で７６°以下であることが好ましい。ちなみに図２８の前記内角は約６８°、図３１の前記内角θは約７５°であった。この範囲内であると前記反強磁性層は前記界面と平行な方向に［１１１］面として表される等価な結晶面が優先配向する。さらに前記固定磁性層３も［１１１］面として表される等価な結晶面が優先配向していることが好ましい。これによってより効果的に抵抗変化率を向上させることができる。

【０１４２】また本発明では、反強磁性層４と固定磁性層３とを成膜し、熱処理を施した後において、前記反強磁性層４と固定磁性層３との結晶配向を透過電子線回折像によって観測し、この透過電子線回折像が以下に説明するような回折図形として得られたなら、反強磁性層４と固定磁性層３との結晶配向は、前記反強磁性層４と固定磁性層３との界面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部は前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いているものと推定することが可能である。

【０１４３】本発明では、まず反強磁性層４と固定磁性層３との界面と平行方向から電子線（ビーム）を入射させ、反強磁性層４及び固定磁性層３のそれぞれについて透過電子線回折像を得る。

【０１４４】前記反強磁性層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面に相当する逆格子点に対応した回折斑点が現れる。前記逆格子点（＝回折斑点）はミラー指数により表される結晶面であり、例えば前記逆格子点は（１１０）面などである。

【０１４５】次に前記回折斑点に指数付けを行う。ビーム原点から回折斑点までの距離ｒは、格子面間隔ｄに反比例するため、ｒを測定することでｄを知ることができる。ＰｔＭｎやＣｏＦｅ，ＮｉＦｅ等の各結晶格子面｛ｈｋｌ｝の面間隔は、ある程度既知であるため、各回折斑点に等価な｛ｈｋｌ｝なる指数付けをすることができる。また、一般的な透過電子線回折像の文献には、単結晶構造の結晶粒の各種の方向に対して観測あるいは計算された、各回折斑点に｛ｈｋｌ｝なる特定の指数付けがなされた透過電子線回折図形が掲載されている。このような文献を用いて、上記の反強磁性層４及び固定磁性層３の透過電子線回折像から得られた回折斑点が、単結晶構造の場合の、どの結晶面の回折斑点と同一あるいは類似しているかを判別し、前記単結晶の場合と同様の指数付け｛ｈｋｌ｝を各個別の回折斑点毎に行う。

【０１４６】そして上記した反強磁性層４の透過電子線回折像と、固定磁性層３の透過電子線回折像とに現れたビーム原点同士を一致させて、各回折像を重ねあわせる。

【０１４７】あるいは反強磁性層４と固定磁性層３の両者に同時に電子線が照射される範囲で透過電子線回折像を得る。

【０１４８】本発明では、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされ且つビーム原点からみたときに膜厚方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第一仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致する（図１６，１８参照；図１６は透過電子線回折像、図１８は図１６に示す回折像の模式図）。これは、前記反強磁性層４と固定磁性層３とが膜面方向に同じ等価な結晶面が優先配向していることを意味する。

【０１４９】さらに本発明では、同じ指数付けがなされ、且つ前記ビーム原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第二仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれているのである（図１６，１８参照）。これは、すなわち膜面と平行な方向に配向しない結晶面については、反強磁性層４と固定磁性層３とで互いに平行関係になっていないことを意味している。あるいは、前記ビーム原点からみたときに、前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点が反強磁性層あるいは強磁性層の一方の回折像のみに現れる状態でも、反強磁性層４と固定磁性層３とで互いに平行関係になっていない。

【０１５０】本発明では、図１７，１９（図１７は透過電子線回折像、図１９は図１７に示す回折像の模式図）に示す比較例とは明らかに異なる回折像を得ることができる。図１７，１９に示す比較例では、同じ指数付けがなされ、且つ前記ビーム原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第二仮想線が、反強磁性層４と固定磁性層３との回折像で互いに一致しているからである。

【０１５１】本発明では図１６に示すような透過電子線回折像が得られた場合には、反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いているものと推測できる。

【０１５２】よって上記した透過電子線回折像が得られるスピンバルブ膜であれば、熱処理を施した段階で反強磁性層４は適切な規則変態を起しており、大きな交換結合磁界を得ることが可能である。

【０１５３】なお本発明では、前記膜厚方向に位置する回折斑点は、代表的に｛１１１｝面として表される等価な結晶面を示していることが好ましい。

【０１５４】また本発明では、前記反強磁性層４と固定

磁性層３との結晶配向を上記とは別の方向から透過電子線回折像によって観測し、この透過電子線回折像が以下に説明するような回折図形として得られたなら、反強磁性層４と固定磁性層３は、膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いているものと推測できる。

【０１５５】すなわち本発明では、反強磁性層４と固定磁性層３との界面と垂直方向から電子線（ビーム）を入射させ、反強磁性層４及び固定磁性層３のそれぞれについて同時に透過電子線回折像を得る（図２０及び図２１参照；図２０は反強磁性層４の回折像の模式図、図２１は固定磁性層３の回折像の模式図）。

【０１５６】前記反強磁性層４及び固定磁性層３の透過電子線回折像には、同じ逆格子面の回折斑点が現れる。前記逆格子面すなわち電子線回折像の投影面は、入射電子線と垂直な結晶面と平行であり、例えば前記逆格子面と平行な結晶面は（１１１）面などである。なお本発明では、前記界面と垂直な方向は、代表的に＜１１１＞方向として表される等価な結晶軸の方向であり、あるいは反強磁性層及び強磁性層の前記界面と平行な結晶面は、代表的に[１１１]面として表される等価な結晶面であることが好ましい。

【０１５７】次に、単結晶構造の場合の透過電子線回折像の文献などを参照して、前記回折斑点に指数付けを行う。反強磁性層４と固定磁性層３には格子定数の違い、すなわち格子面間隔の違いがあるため反強磁性層４の透過電子線回折斑点と、固定磁性層３の透過電子線回折斑点とは、それらの斑点のビーム原点との距離の違いにより容易に判別できる（図２２参照）。

【０１５８】本発明では、前記回折斑点のうち、反強磁性層４の回折像と、固定磁性層３の回折像とで同じ指数付けがなさた、ある回折斑点からビーム原点までを結んだ仮想線（仮想線①と仮想線②、及び仮想線③と仮想線④）は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれた状態となっている（図２２参照）。これは、膜面と平行な方向に配向した結晶面内に存在する、ある同じ等価な結晶軸の方位が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いていることを意味する。あるいは前記回折斑点のうち、ある指数付けがされた回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる状態でも反強磁性層４と固定磁性層３とで互いに異なる方向を向いていることを意味する。

【０１５９】上記の本発明における透過電子線回折像は、図２３ないし図２５（図２３は反強磁性層の回折像の模式図、図２４は固定磁性層の回折像の模式図、図２５は図２３と図２４とを重ねあわせた模式図）に示す比較例の透過電子線回折像とは明らかに異なることがわかる。

【０１６０】図２５に示すように、ある回折斑点からビーム原点まで結んだ仮想線⑤⑥は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致しているからである。

【０１６１】本発明では、図２０ないし図２２に示す透過電子線回折像が得られた場合には、反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向するが、前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いていると推測される。

【０１６２】よって上記した透過電子線回折像が得られるスピンバルブ膜であれば、熱処理を施した段階で反強磁性層４は適切な規則変態を起しており、大きな交換結合磁界を得ることが可能である。

【０１６３】以上のように本発明におけるスピンバルブ型薄膜素子の結晶配向、結晶粒界及び双晶境界の特徴点を説明したが、このような結晶配向、結晶粒界及び双晶境界を得るには、前記反強磁性層４と固定磁性層３とを成膜したとき、前記反強磁性層４の原子が前記固定磁性層３の結晶構造に強固に拘束されないようにしなければならない。拘束力を弱めるためには、前記反強磁性層４と固定磁性層３の界面でいわゆる非整合状態になっていることが好ましい。

【０１６４】非整合状態とは、反強磁性層４の原子の配列と固定磁性層３の原子の配列が前記界面で１対１に対応しない状態のことを言うが、このような非整合状態を作るには前記反強磁性層４の格子定数を前記固定磁性層３の格子定数に比して広げておくことが必要である。

【０１６５】それに加えて前記反強磁性層４は熱処理によって適切な規則変態を起さなければならない。前記固定磁性層３との界面が非整合状態であっても前記反強磁性層４が規則変態を引き起こさない場合には、結局、交換結合磁界は低くなってしまう。

【０１６６】上記した成膜段階における非整合状態、及び規則変態を起すか否かの適正化は、反強磁性層４を構成する各構成元素の組成比や成膜条件によるところが大きいと考えられる。

【０１６７】本発明では、反強磁性層４の元素Ｘあるいは元素Ｘ＋Ｘ′の原子％を４５（ａｔ％）以上６０（ａｔ％）以下に設定することが好ましい。これによって成膜段階において、固定磁性層３との界面が非整合状態にされ、しかも前記反強磁性層４は熱処理によって適切な規則変態を起すものと推測される。

【０１６８】そして上記の組成範囲内で形成された反強磁性層４を使用することにより、熱処理後のスピンバルブ型薄膜素子では、前記反強磁性層４と固定磁性層３との結晶配向を、膜面と平行な方向に同じ等価な結晶面を優先配向させ、しかも前記反強磁性層４及び固定磁性層

３の前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部を互いに異なる方向に向かせることが可能である。また前記反強磁性層４の結晶粒界と、固定磁性層３の結晶粒界とを界面の少なくとも一部で不連続な状態にすることができる。また前記反強磁性層４を[１１１]面配向させ、さらに前記反強磁性層４に形成される双晶境界を前記界面と非平行で形成することができる。上記の組成範囲内であると後述する実験結果によれば１．５８×１０^4（Ａ／ｍ）以上の交換結合磁界を得ることが可能である。

【０１６９】また本発明では、前記元素Ｘあるいは元素Ｘ＋Ｘ′の原子％を、４９（ａｔ％）以上で５６．５（ａｔ％）以下に設定することが好ましい。これにより７．９×１０^4（Ａ／ｍ）以上の交換結合磁界を得ることが可能である。

【０１７０】また非整合状態を形成するに重要な前記成膜条件とは、前記反強磁性層４、固定磁性層３を成膜する際に用いられるＡｒガス圧や、熱処理条件、さらには前記反強磁性層４を成膜する際の基板とターゲット間の距離、基板温度、基板バイアス電圧、成膜速度などである。

【０１７１】本発明では例えば前記Ａｒガス圧を３ｍＴｏｒｒとする。また熱処理温度を２００℃以上で３００℃以下とし、熱処理時間を２時間以上で１０$^{-6}$Ｔｏｒｒ以下の真空中で磁場中熱処理をする。また前記基板とターゲット間の距離を８０ｍｍとする。

【０１７２】また本発明では、上記した結晶配向を有するスピンバルブ型薄膜素子では、熱処理後において、前記反強磁性層４と固定磁性層３との界面の少なくとも一部を非整合状態にすることが可能である。

【０１７３】また上記した反強磁性層４と固定磁性層３との結晶配向、及び透過電子線回折像は、シードレイヤ２２と反強磁性層４間にも観測される。すなわち前記シードレイヤ２２と反強磁性層４との間においても膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記シードレイヤ２２と反強磁性層４とで互いに異なる方向を向いている。

【０１７４】また膜厚方向と平行な方向の断面において、前記シードレイヤ２２の結晶粒界と反強磁性層４の結晶粒界との少なくとも一部は不連続な状態となっている。

【０１７５】このような結晶配向及び結晶粒界がシードレイヤ２２と反強磁性層４との間に存在すると、前記シードレイヤ２２と反強磁性層４との界面では少なくとも一部が非整合状態を保ちやすく、したがって前記反強磁性層４は前記シードレイヤ２２の結晶構造に拘束されずに適切な規則変態を起しており、さらに大きな交換結合磁界が得られるのである。

【０１７６】また本発明では前記反強磁性層４の膜厚を

７ｎｍ～３０ｎｍの範囲内で形成することが好ましい。このように本発明では前記反強磁性層４の膜厚を薄くしてもなお適切な交換結合磁界を発生させることができる。

【０１７７】図２は、別のスピンバルブ型薄膜素子の構造を示す部分断面図である。このスピンバルブ型薄膜素子では、下から下地層６、ＮｉＦｅ合金膜９とＣｏ膜１０とから成るフリー磁性層１、非磁性中間層２、及びＣｏ膜１１、Ｒｕ膜１２、及びＣｏ膜１３から成る固定磁性層３、反強磁性層４及び保護層７が積層されている。そして前記積層膜の両側にはハードバイアス層５，５及び導電層８，８が形成されている。

【０１７８】なお各層の材質等に関しては図１に説明したスピンバルブ型薄膜素子と同じである。

【０１７９】図２に示すスピンバルブ型薄膜素子では、反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いている。

【０１８０】また前記反強磁性層４と固定磁性層３とを膜厚と平行な方向（図示Ｚ方向）から断面としてみたときに、前記反強磁性層４の結晶粒界と前記固定磁性層３の結晶粒界は、界面の少なくとも一部において不連続な状態になっている。

【０１８１】このため前記界面の少なくとも一部は非整合状態を保ち、前記反強磁性層４は熱処理によって適切な規則変態がなされており、大きな交換結合磁界を得ることが可能である。

【０１８２】なお反強磁性層４と固定磁性層３とが膜面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向していることが好ましい。また前記結晶面内において、代表的に＜１１０＞方向として表される等価な結晶軸の方向が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いていることが好ましい。

【０１８３】またこの実施形態のように前記反強磁性層４が固定磁性層３の上に形成されているときは、シードレイヤ、反強磁性層４及び固定磁性層３の順に積層される場合に比べて前記反強磁性層４を[１１１]面配向させることは難しいが、ただし成膜条件等の制御によって前記反強磁性層４を[１１１]面配向にすることは可能である。そしてこの場合、本発明では、前記反強磁性層４には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。これによって抵抗変化率を向上させることができると共に、前記反強磁性層４は適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。

【０１８４】また図２に示すスピンバルブ型薄膜素子で

は、前記界面と平行方向から電子線（ビーム）を入射させて得られた反強磁性層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされ且つビーム原点からみたときに膜厚方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第一仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致している。

【０１８５】しかも本発明では、同じ指数付けがなされ、且つ前記ビーム原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記原点とを結んだ第二仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれているのである。あるいは前記ビーム原点からみたときに、前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点が反強磁性層あるいは強磁性層の一方の回折像のみに現れる。

【０１８６】上記の場合、前記膜厚方向に位置する回折斑点は、代表的に｛１１１｝面として表される等価な結晶面であることが好ましい。

【０１８７】あるいは図２に示すスピンバルブ型薄膜素子では、前記界面と垂直方向から電子線（ビーム）を入射させて得られた反強磁性層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされた、ある回折斑点からビーム原点までを結んだ仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは前記回折斑点のうち、ある指数付けがされた回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０１８８】上記の場合、前記界面と垂直な方向は、代表的に<１１１>方向として表される等価な結晶軸の方向であり、あるいは反強磁性層及び強磁性層の前記界面と平行な結晶面は、代表的に[１１１]面として表される等価な結晶面であることが好ましい。

【０１８９】上記のような透過電子線回折像が得られると、反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いているものと推測できる。

【０１９０】そして上記した透過電子線回折像を有するスピンバルブ型薄膜素子であると、前記反強磁性層４は熱処理によって適切な規則変態を起しており、従来に比べて大きな交換結合磁界が得られる。

【０１９１】また図２に示すスピンバルブ型薄膜素子では、反強磁性層４を構成する元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は４５（ａｔ％）以上６０（ａｔ％）以下であることが好ましい。これにより１．５８×１０^4（Ａ／ｍ）以上の交換結合磁界を得ることが可能である。

【０１９２】また本発明では、前記元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は、４９（ａｔ％）以上５７（ａｔ％）以下であることが好ましい。これにより７．９×１０^4（Ａ／ｍ）以上の交換結合磁界を得ることが可能である。

【０１９３】次に図３は本発明における別のスピンバルブ型薄膜素子の構造を示す部分断面図である。

【０１９４】図３では下から下地層６、シードレイヤ２２、反強磁性層４、固定磁性層３、非磁性中間層２、フリー磁性層１が積層されている。

【０１９５】前記下地層６は、Ｔａ，Ｈｆ，Ｎｂ，Ｚｒ，Ｔｉ，Ｍｏ，Ｗのうち少なくとも１種以上の元素で形成されていることが好ましい。

【０１９６】また前記シードレイヤ２２は、結晶構造が主として面心立方晶からなり、しかも反強磁性層４との界面と平行な方向に、代表的に[１１１]面として表される等価な結晶面が優先配向していることが好ましい。なお前記シードレイヤ２２の材質等に関しては図１で説明したものと同様である。

【０１９７】前記シードレイヤ２２を反強磁性層４の下に形成することで、前記シードレイヤ２２上に形成される反強磁性層４、固定磁性層３、非磁性中間層２及びフリー磁性層１も前記シードレイヤ２２と同じ等価な結晶面が膜面と平行な方向に優先配向する。

【０１９８】また図３では固定磁性層３が、Ｃｏ膜１１，１３、Ｒｕ膜１２の３層膜で形成されているが、他の材質が使用されても良く、また３層膜ではなく例えば単層膜で形成されてもかまわない。

【０１９９】またフリー磁性層１は、ＮｉＦｅ合金膜９とＣｏ膜１０との２層膜で形成されているが、他の材質が使用されても良く、また２層膜ではなく例えば単層膜で形成されてもかまわない。

【０２００】図３に示すスピンバルブ型薄膜素子では、反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いている。

【０２０１】また前記反強磁性層４と固定磁性層３とを膜厚と平行な方向（図示Ｚ方向）から断面としてみたときに、前記反強磁性層４の結晶粒界と前記固定磁性層３の結晶粒界が前記界面の少なくとも一部で不連続な状態になっている。

【０２０２】このため前記界面の少なくとも一部は非整合状態を保ち、前記反強磁性層４は熱処理によって適切な規則変態がなされており、大きな交換結合磁界を得ることが可能である。

【０２０３】なお反強磁性層４と固定磁性層３膜面と平行な方向に代表的に［１１１］面として表される等価な結晶面が優先配向していることが好ましい。また前記結晶面内において、代表的に＜１１０＞方向として表される等価な結晶軸の方向が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いていることが好ましい。

【０２０４】また本発明では、前記反強磁性層４と固定磁性層３とが前記界面と平行な方向に代表的に［１１１］面として表される等価な結晶面が優先配向し、しかも前記反強磁性層４には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。これによって抵抗変化率を向上させることができると共に、前記反強磁性層４は適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。

【０２０５】また図３に示すスピンバルブ型薄膜素子では、前記界面と平行方向から電子線（ビーム）を入射させて得られた反強磁性層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされ且つビーム原点からみたときに膜厚方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第一仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致している。

【０２０６】しかも本発明では、同じ指数付けがなされ、且つ前記ビーム原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第二仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。また前記ビーム原点からみたときに、前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２０７】上記の場合、前記膜厚方向に位置する回折斑点は、代表的に｛１１１｝面として表される等価な結晶面であることが好ましい。

【０２０８】あるいは図３に示すスピンバルブ型薄膜素子では、前記界面と垂直方向から電子線（ビーム）を入射させて得られた反強磁性層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされた、ある回折斑点からビーム原点までを結んだ仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは前記回折斑点のうち、ある指数付けがされた回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２０９】上記の場合、前記界面と垂直な方向は、代表的に＜１１１＞方向として表される等価な結晶軸の方向であり、あるいは、反強磁性層及び強磁性層の前記界面と平行な結晶面は、代表的に［１１１］面として表される等価な結晶面であることが好ましい。

【０２１０】上記のような透過電子線回折像が得られると、反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いているものと推測できる。上記した透過電子線回折像を有するスピンバルブ型薄膜素子であると、前記反強磁性層４は熱処理によって適切な規則変態を起しており、従来に比べて大きな交換結合磁界が得られる。

【０２１１】また図３に示すスピンバルブ型薄膜素子では、反強磁性層４を構成する元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は４５（ａｔ％）以上６０（ａｔ％）以下であることが好ましい。これにより１．５８×１０^{4}（Ａ／ｍ）以上の交換結合磁界を得ることが可能である。

【０２１２】また本発明では、前記元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は、４９（ａｔ％）以上５６．５（ａｔ％）以下であることが好ましい。これにより７．９×１０^{4}（Ａ／ｍ）以上の交換結合磁界を得ることが可能である。

【０２１３】また図３に示すように前記フリー磁性層１上には、トラック幅方向（図示Ｘ方向）にトラック幅Ｔｗの間隔を開けてエクスチェンジバイアス層（反強磁性層）１６，１６が形成されている。

【０２１４】なおこのエクスチェンジバイアス層１６は、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）、好ましくはＰｔＭｎ合金、またはＸ―Ｍｎ―Ｘ′合金（ただしＸ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成されている。

【０２１５】本発明では、前記エクスチェンジバイアス層１６とフリー磁性層１は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部の方向は前記エクスチェンジバイアス層１６とフリー磁性層１とで、互いに異なる方向を向いている。

【０２１６】また前記エクスチェンジバイアス層１６とフリー磁性層１とを膜厚と平行な方向（図示Ｚ方向）から断面としてみたときに、前記エクスチェンジバイアス層１６の結晶粒界と前記フリー磁性層１の結晶粒界は界面の少なくとも一部において不連続な状態になっている。

【０２１７】このため前記界面の少なくとも一部は非整

合状態を保ち、前記エクスチェンジバイアス層１６は熱処理によって適切な規則変態がなされており、大きな交換結合磁界を得ることが可能である。

【０２１８】なおエクスチェンジバイアス層１６とフリー磁性層１は膜面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向していることが好ましい。また前記結晶面内において、代表的に＜１１０＞方向として表される等価な結晶軸の方向が、エクスチェンジバイアス層１６とフリー磁性層１とで互いに異なる方向を向いていることが好ましい。

【０２１９】また本発明では、前記エクスチェンジバイアス層１６が前記界面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向し、しかも前記エクスチェンジバイアス層１６には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。このため前記エクスチェンジバイアス層１６は適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。

【０２２０】また図３に示すスピンバルブ型薄膜素子では、前記界面と平行方向から電子線（ビーム）を入射させて得られたエクスチェンジバイアス層１６及びフリー磁性層１の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、エクスチェンジバイアス層１６の回折像とフリー磁性層１の回折像とで同じ指数付けがなされ且つビーム原点からみたときに膜厚方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第一仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致している。

【０２２１】しかも本発明では、同じ指数付けがなされ、且つ前記ビーム原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第二仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれているのである。あるいは前記ビーム原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点が反強磁性層あるいは強磁性層の一方の回折像にのみ現れるのである。

【０２２２】上記の場合、前記膜厚方向に位置する回折斑点は、代表的に｛１１１｝面として表される等価な結晶面であることが好ましい。

【０２２３】あるいは図３に示すスピンバルブ型薄膜素子では、前記界面と垂直方向から電子線（ビーム）を入射させて得られたエクスチェンジバイアス層１６及びフリー磁性層１の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、エクスチェンジバイアス層１６の回折像とフリー磁性層１の回折像とで同じ指数付けがなされた、ある回折斑点からビーム原点までを結んだ仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは前記回折斑点のうち、ある指数付けがされた回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２２４】上記の場合、前記界面と垂直な方向は、代表的に＜１１１＞方向として表される等価な結晶軸の方向であり、あるいは、反強磁性層及び強磁性層の前記界面と平行な結晶面は、代表的に[１１１]面として表される等価な結晶面であることが好ましい。

【０２２５】上記のような透過電子線回折像を有するスピンバルブ型薄膜素子であると、エクスチェンジバイアス層１６とフリー磁性層１は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記エクスチェンジバイアス層１６とフリー磁性層１とで互いに異なる方向を向いているものと推測される。そして前記透過電子線回折像を有するスピンバルブ型薄膜素子では、前記エクスチェンジバイアス層１６は熱処理によって適切な規則変態を起しており、従来に比べて大きな交換結合磁界が得られる。

【０２２６】前記フリー磁性層１の両側端部では、エクスチェンジバイアス層１６間での交換結合磁界によりフリー磁性層１が図示Ｘ方向に単磁区化され、フリー磁性層１のトラック幅Ｔｗ領域の磁化は、外部磁界に対して反応する程度に図示Ｘ方向に適性に揃えられている。

【０２２７】このようにして形成されたシングルスピンバルブ型磁気抵抗効果素子では、図示Ｙ方向の外部磁界により、フリー磁性層１のトラック幅Ｔｗ領域の磁化が図示Ｘ方向から図示Ｙ方向に変化する。このフリー磁性層１内での磁化の方向の変動と、固定磁性層３の固定磁化方向（図示Ｙ方向）との関係で電気抵抗が変化し、この電気抵抗値の変化に基づく電圧変化により、記録媒体からの洩れ磁界が検出される。

【０２２８】図４は、本発明における他のスピンバルブ型薄膜素子の構造を示す部分断面図である。

【０２２９】図４に示すスピンバルブ型薄膜素子では、トラック幅方向（図示Ｘ方向）にトラック幅Ｔｗの間隔を開けた一対のシードレイヤ２２が形成され、前記シードレイヤ２２の上にエクスチェンジバイアス層１６，１６が形成されている。

【０２３０】前記一対のシードレイヤ２２及びエクスチェンジバイアス層１６間は、SiO_2やAl_2O_3等の絶縁材料で形成された絶縁層１７によって埋められている。

【０２３１】そして前記エクスチェンジバイアス層１６及び絶縁層１７上にはフリー磁性層１が形成されている。

【０２３２】前記エクスチェンジバイアス層１６はＸ－Ｍｎ合金、あるいはＸ－Ｍｎ－Ｘ′合金で形成され、前

記元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は４５（ａｔ％）以上６０（ａｔ％）以下であることが好ましく、より好ましくは４９（ａｔ％）以上５６．５（ａｔ％）以下である。

【０２３３】熱処理を施すことにより前記エクスチェンジバイアス層１６はフリー磁性層１の結晶構造に拘束されず、適切な規則変態を起し、従来に比べて大きな交換結合磁界を得ることができる。

【０２３４】本発明では熱処理後において、前記エクスチェンジバイアス層１６とフリー磁性層１は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記エクスチェンジバイアス層１６とフリー磁性層１とで互いに異なる方向を向いている。

【０２３５】また前記エクスチェンジバイアス層１６とフリー磁性層１とを膜厚と平行な方向（図示Ｚ方向）から断面としてみたときに、前記エクスチェンジバイアス層１６の結晶粒界と前記フリー磁性層１の結晶粒界は界面の少なくとも一部において不連続な状態になっている。

【０２３６】このため前記界面の少なくとも一部は非整合状態を保ち、前記エクスチェンジバイアス層１６は熱処理によって適切な規則変態がなされており、大きな交換結合磁界を得ることが可能である。

【０２３７】なおエクスチェンジバイアス層１６とフリー磁性層１は膜面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向していることが好ましい。また前記結晶面内において、代表的に＜１１０＞方向として表される等価な結晶軸の方向が、エクスチェンジバイアス層１６とフリー磁性層１とで互いに異なる方向を向いていることが好ましい。

【０２３８】また本発明では、前記エクスチェンジバイアス層１６が前記界面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向し、しかも前記エクスチェンジバイアス層１６には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。このため、前記エクスチェンジバイアス層１６は適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。

【０２３９】また図４に示すスピンバルブ型薄膜素子では、前記界面と平行方向から電子線（ビーム）を入射させて得られたエクスチェンジバイアス層１６及びフリー磁性層１の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、エクスチェンジバイアス層１６の回折像とフリー磁性層１の回折像とで同じ指数付けがなされ且つビーム原点からみたときに膜厚方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第一仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致している。

【０２４０】しかも本発明では、同じ指数付けがなされ、且つ前記原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第二仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは前記ビーム原点からみたときに、前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点が反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２４１】上記の場合、前記膜厚方向に位置する回折斑点は、代表的に｛１１１｝面として表される等価な結晶面を示していることが好ましい。

【０２４２】あるいは図４に示すスピンバルブ型薄膜素子では、前記界面と垂直方向から電子線（ビーム）を入射させて得られたエクスチェンジバイアス層１６及びフリー磁性層１の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、エクスチェンジバイアス層１６の回折像とフリー磁性層１の回折像とで同じ指数付けがなされた、ある回折斑点からビーム原点までを結んだ仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは、前記回折斑点のうち、ある指数付けがされた回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２４３】上記の場合、前記界面と垂直な方向は、代表的に＜１１１＞方向として表される等価な結晶軸の方向であり、あるいは、反強磁性層及び強磁性層の前記界面と平行な結晶面は、代表的に[１１１]面として表される等価な結晶面であることが好ましい。

【０２４４】上記のような透過電子線回折像が得られると、エクスチェンジバイアス層１６とフリー磁性層１は膜面と平行な方向に同じ等価な結晶面が優先配向し、前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記エクスチェンジバイアス層１６とフリー磁性層１とで互いに異なる方向を向いているものと推測できる。そして上記したスピンバルブ型薄膜素子であると、前記エクスチェンジバイアス層１６は熱処理によって適切な規則変態を起しており、従来に比べて大きな交換結合磁界が得られる。

【０２４５】前記フリー磁性層１の両側端部では、エクスチェンジバイアス層１６間での交換結合磁界により図示Ｘ方向に単磁区化され、フリー磁性層１のトラック幅Ｔｗ領域の磁化は、外部磁界に対して反応する程度に図示Ｘ方向に適性に揃えられている。

【０２４６】図４に示すように前記フリー磁性層１の上には非磁性中間層２が形成され、さらに前記非磁性中間層２の上には固定磁性層３が形成されている。さらに前記固定磁性層３の上には反強磁性層４が形成されている。

【０２４７】本発明では熱処理後において、前記反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いている。

【０２４８】また前記反強磁性層４と固定磁性層３とを膜厚と平行な方向（図示Ｚ方向）から断面としてみたときに、前記反強磁性層４の結晶粒界と前記固定磁性層３の結晶粒界は界面の少なくとも一部において不連続な状態になっている。

【０２４９】このため前記界面の少なくとも一部は非整合状態を保ち、前記反強磁性層４は熱処理によって適切な規則変態がなされており、大きな交換結合磁界を得ることが可能である。

【０２５０】なお反強磁性層４と固定磁性層３膜面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向していることが好ましい。また前記結晶面内において、代表的に＜１１０＞方向として表される等価な結晶軸の方向が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いていることが好ましい。

【０２５１】また本発明では、前記反強磁性層４が前記界面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向し、しかも前記反強磁性層４には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。これによって抵抗変化率を向上させることができると共に、前記反強磁性層４は適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。

【０２５２】また図４に示すスピンバルブ型薄膜素子では、前記界面と平行方向から電子線（ビーム）を入射させて得られた反強磁性層層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされ且つビーム原点からみたときに膜厚方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第一仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致している。

【０２５３】しかも本発明では、同じ指数付けがなされ、且つ前記ビーム原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第二仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは前記ビーム原点からみたときに、前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点が反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２５４】上記の場合、前記膜厚方向に位置する回折斑点は、代表的に｛１１１｝面として表される等価な結晶面を示していることが好ましい。

【０２５５】あるいは図４に示すスピンバルブ型薄膜素子では、前記界面と垂直方向から電子線（ビーム）を入射させて得られた反強磁性層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされた、ある回折斑点からビーム原点までを結んだ仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは、前記回折斑点のうち、ある指数付けがされた回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２５６】上記の場合、前記界面と垂直な方向は、代表的に＜１１１＞方向として表される等価な結晶軸の方向であり、あるいは反強磁性層及び強磁性層の前記界面と平行な結晶面は、代表的に[１１１]面として表される等価な結晶面であることが好ましい。

【０２５７】上記のような透過電子線回折像が得られると、反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部は、反強磁性層４と固定磁性層３とで互いに異なる方向を向いているものと推測できる。そして上記した透過電子線回折像を有するスピンバルブ型薄膜素子であると、前記反強磁性層４は熱処理によって適切な規則変態を起しており、従来に比べて大きな交換結合磁界が得られる。

【０２５８】図５は本発明におけるデュアルスピンバルブ型薄膜素子の構造を示す部分断面図である。

【０２５９】図５に示すように、下から下地層６、シードレイヤ２２、反強磁性層４、固定磁性層３、非磁性中間層２、およびフリー磁性層１が連続して積層されている。前記フリー磁性層１は３層膜で形成され、例えばＣｏ膜１０，１０とＮｉＦｅ合金膜９で構成される。さらに前記フリー磁性層１の上には、非磁性中間層２、固定磁性層３、反強磁性層４、および保護層７が連続して積層されている。

【０２６０】また、下地層６から保護層７までの多層膜の両側にはハードバイアス層５，５、導電層８，８が積層されている。なお、各層は図１で説明した材質と同じ材質で形成されている。

【０２６１】この実施例では、フリー磁性層１よりも図示下側に位置する反強磁性層４の下にはシードレイヤ２２が形成されている。さらに前記反強磁性層４を構成する元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は、４５（ａｔ％）以上６０（ａｔ％）以上で形成されることが好ましく、より好ましくは４９（ａｔ％）以上５６．５（ａｔ％）以下である。

【０２６２】そして本発明では熱処理後において、前記

反強磁性層４と固定磁性層３の結晶配向は、前記反強磁性層４と固定磁性層３との界面と平行な方向に同じ等価な結晶面が優先配向し、前記反強磁性層４と固定磁性層３の前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、互いに異なる方向を向いている。

【０２６３】また前記反強磁性層４と固定磁性層３とを膜厚と平行な方向（図示Ｚ方向）から断面としてみたときに、前記反強磁性層４の結晶粒界と前記固定磁性層３の結晶粒界は界面の少なくとも一部において不連続な状態になっている。

【０２６４】このため前記界面の少なくとも一部は非整合状態を保ち、前記反強磁性層４は熱処理によって適切な規則変態がなされており、大きな交換結合磁界を得ることが可能である。

【０２６５】なお反強磁性層４と固定磁性層３膜面と平行な方向に代表的に［１１１］面として表される等価な結晶面が優先配向していることが好ましい。また前記結晶面内において、代表的に＜１１０＞方向として表される等価な結晶軸の方向が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いていることが好ましい。

【０２６６】また本発明では、前記反強磁性層４が前記界面と平行な方向に代表的に［１１１］面として表される等価な結晶面が優先配向し、しかも前記反強磁性層４には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。これによって抵抗変化率を向上させることができると共に、前記反強磁性層４は適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。

【０２６７】また図５に示すデュアルスピンバルブ型薄膜素子では、フリー磁性層１よりも下側に形成された固定磁性層３及び反強磁性層４のみならず、積層膜全体の結晶配向が、上記と同様の結晶配向を有するものとなっている。

【０２６８】すなわち本発明では、フリー磁性層１よりも上側に形成された反強磁性層４及び固定磁性層３もまた膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記反強磁性層４と固定磁性層３とで互いに異なる方向を向いているのである。

【０２６９】また前記反強磁性層４と固定磁性層３とを膜厚と平行な方向（図示Ｚ方向）から断面としてみたときに、前記反強磁性層４の結晶粒界と前記固定磁性層３の結晶粒界は界面の少なくとも一部において不連続な状態になっている。

【０２７０】このため前記界面の少なくとも一部は非整合状態を保ち、前記反強磁性層４は熱処理によって適切な規則変態がなされており、大きな交換結合磁界を得ることが可能である。

【０２７１】なお反強磁性層４と固定磁性層３膜面と平行な方向に代表的に［１１１］面として表される等価な結晶面が優先配向していることが好ましい。また前記結晶面内において、代表的に＜１１０＞方向として表される等価な結晶軸の方向が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いていることが好ましい。

【０２７２】また本発明では、前記反強磁性層４が前記界面と平行な方向に代表的に［１１１］面として表される等価な結晶面が優先配向し、しかも前記反強磁性層４には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。これによって抵抗変化率を向上させることができると共に、前記反強磁性層４は適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。

【０２７３】また図５に示すスピンバルブ型薄膜素子では、前記界面と平行方向から電子線（ビーム）を入射させて得られた、反強磁性層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされ且つビーム原点からみたときに膜厚方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第一仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致する。

【０２７４】しかも本発明では、同じ指数付けがなされ、且つ前記ビーム原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第二仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは前記ビーム原点からみたときに、前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点が反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２７５】上記の場合、前記膜厚方向に位置する回折斑点は、代表的に｛１１１｝面として表される等価な結晶面を示していることが好ましい。

【０２７６】あるいは図５に示すスピンバルブ型薄膜素子では、前記界面と垂直方向から電子線（ビーム）を入射させて得られた、反強磁性層４及び固定磁性層３の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、反強磁性層４の回折像と固定磁性層３の回折像とで同じ指数付けがなされた、ある回折斑点からビーム原点までを結んだ仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは、前記回折斑点のうち、ある指数付けがされた回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２７７】上記の場合、前記界面と垂直な方向は、代表的に＜１１１＞方向として表される等価な結晶軸の方向であり、あるいは、反強磁性層及び強磁性層の前記界面と平行な結晶面は、代表的に［１１１］面として表される等価な結晶面であることが好ましい。

【０２７８】上記のような透過電子線回折像が得られると、反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いているものと推測される。よって上記した透過電子線回折像を有するスピンバルブ型薄膜素子であると、前記反強磁性層４は熱処理によって適切な規則変態を起しており、従来に比べて大きな交換結合磁界が得られる。

【０２７９】図６、７は、本発明のＡＭＲ型磁気抵抗効果素子の構造を示す断面図である。図６に示すように、下から軟磁性層（ＳＡＬ層）１８、非磁性層（ＳＨＵＮＴ層）１９、および磁気抵抗層（ＭＲ層）２０が連続して積層されている。

【０２８０】例えば前記軟磁性層１８は、Ｆｅ－Ｎｉ－Ｎｂ合金、非磁性層１９は、Ｔａ膜、磁気抵抗層２０は、ＮｉＦｅ合金により形成されている。

【０２８１】前記磁気抵抗層２０の上には、トラック幅Ｔｗを開けたトラック幅方向（Ｘ方向）の両側の部分にエクスチェンジバイアス層（反強磁性層）２１，２１が形成されている。導電層は図示しないが、例えば前記エクスチェンジバイアス層２１，２１の上に形成される。

【０２８２】また図７では、トラック幅方向（図示Ｘ方向）にトラック幅Ｔｗの間隔を開けて一対のシードレイヤ２２が形成されている。前記シードレイヤ２２上にはエクスチェンジバイアス層２１，２１が形成され、前記一対のシードレイヤ２２及びエクスチェンジバイアス層２１，２１間がSiO_2やAl_2O_3等の絶縁材料で形成された絶縁層２６によって埋められている。

【０２８３】そして前記エクスチェンジバイアス層２１，２１及び前記絶縁層２６上に、磁気抵抗層（ＭＲ層）２０、非磁性層（ＳＨＵＮＴ層）１９、及び軟磁性層（ＳＡＬ層）１８が積層される。

【０２８４】本発明では、図６及び７に示すエクスチェンジバイアス層２１と磁気抵抗層２０は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記エクスチェンジバイアス層２１と磁気抵抗層２０とで互いに異なる方向を向いているのである。

【０２８５】また前記エクスチェンジバイアス層２１と磁気抵抗層２０とを膜厚と平行な方向（図示Ｚ方向）から断面としてみたときに、前記エクスチェンジバイアス層２１の結晶粒界と前記磁気抵抗層２０の結晶粒界は界面の少なくとも一部において不連続な状態になっている。

【０２８６】このため前記界面の少なくとも一部は非整合状態を保ち、前記エクスチェンジバイアス層２１は熱処理によって適切な規則変態がなされており、大きな交換結合磁界を得ることが可能である。

【０２８７】なおエクスチェンジバイアス層２１と磁気抵抗層２０は膜面と平行な方向に代表的に［１１１］面として表される等価な結晶面が優先配向していることが好ましい。また前記結晶面内において、代表的に＜１１０＞方向として表される等価な結晶軸の方向が、エクスチェンジバイアス層２１と磁気抵抗層２０とで互いに異なる方向を向いていることが好ましい。

【０２８８】また本発明では、前記エクスチェンジバイアス層２１が前記界面と平行な方向に代表的に［１１１］面として表される等価な結晶面が優先配向し、しかも前記エクスチェンジバイアス層２１には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。このため前記エクスチェンジバイアス２１は適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。

【０２８９】また図６，７に示すＡＭＲ型薄膜素子では、前記界面と平行方向から電子線（ビーム）を入射させて得られたエクスチェンジバイアス層２１及び磁気抵抗層２０の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、エクスチェンジバイアス層２１の回折像と磁気抵抗層２０の回折像とで同じ指数付けがなされ且つビーム原点からみたときに膜厚方向に位置する、ある結晶面を示す回折斑点と、前記ビーム原点とを結んだ第一仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いに一致している。

【０２９０】しかも本発明では、同じ指数付けがなされ、且つ前記原点からみたときに前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点と、前記原点とを結んだ第二仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは前記ビーム原点からみたときに、前記膜厚方向以外の方向に位置する、ある結晶面を示す回折斑点が反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２９１】上記の場合、前記膜厚方向に位置する回折斑点は、代表的に｛１１１｝面として表される等価な結晶面を示していることが好ましい。

【０２９２】あるいは図６，７に示すＡＭＲ型薄膜素子では、前記界面と垂直方向から電子線（ビーム）を入射させて得られたエクスチェンジバイアス層２１及び磁気抵抗層２０の透過電子線回折像には、それぞれの層の各結晶面を表す逆格子点に対応した回折斑点が現れ、前記回折斑点のうち、エクスチェンジバイアス層２１の回折像と磁気抵抗層２０の回折像とで同じ指数付けがなされ

た、ある回折斑点からビーム原点までを結んだ仮想線は、前記反強磁性層の回折像及び強磁性層の回折像とで互いにずれている。あるいは、前記回折斑点のうち、ある指数付けがされた回折斑点が、反強磁性層あるいは強磁性層の一方の回折像にのみ現れる。

【０２９３】上記の場合、前記界面と垂直な方向は、代表的に<１１１>方向として表される等価な結晶軸の方向であり、あるいは、反強磁性層及び強磁性層の前記界面と平行な結晶面は、代表的に[１１１]面として表される等価な結晶面であることが好ましい。

【０２９４】上記のような透過電子線回折像が得られると、エクスチェンジバイアス層２１と磁気抵抗層２０は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、前記エクスチェンジバイアス層２１と磁気抵抗層２０とで互いに異なる方向を向いていると考えられる。そして上記した透過電子線回折像を有するスピンバルブ型薄膜素子であると、前記エクスチェンジバイアス層２１は熱処理によって適切な規則変態を起しており、従来に比べて大きな交換結合磁界が得られる。

【０２９５】上記した図６及び図７に示すＡＭＲ型薄膜素子では、前記エクスチェンジバイアス層２１，２１と磁気抵抗層２０との界面で発生する交換結合磁界により、図６、７に示す磁気抵抗層２０のＥ領域が、図示Ｘ方向に単磁区化される。そしてこれに誘発されて前記磁気抵抗層２０のＤ領域の磁化が図示Ｘ方向に揃えられる。また、検出電流が磁気抵抗層２０を流れる際に発生する電流磁界が、軟磁性層１８にＹ方向に印加され、軟磁性層１８がもたらす静磁結合エネルギーにより、磁気抵抗層２０のＤ領域に横バイアス磁界がＹ方向に与えられる。Ｘ方向に単磁区化された磁気抵抗層２０のＤ領域にこの横バイアス層が与えられることにより、磁気抵抗層２０のＤ領域の磁界変化に対する抵抗変化（磁気抵抗効果特性：Ｈ―Ｒ効果特性）が直線性を有する状態に設定される。

【０２９６】記録媒体の移動方向はＺ方向であり、図示Ｙ方向に漏れ磁界が与えられると、磁気抵抗層２０のＤ領域の抵抗値が変化し、これが電圧変化として検出される。

【０２９７】なお上記した図１ないし図７に示す磁気抵抗効果素子の製造方法についてであるが、本発明では特に反強磁性層４を以下のようにして形成することが好ましい。

【０２９８】上記したように、前記反強磁性層４の元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は、４５（ａｔ％）以上６０（ａｔ％）以下であることが好ましく、より好ましくは４９（ａｔ％）以上５６．５（ａｔ％）以下であり、この範囲内であると後述する実験結果に示すように、大きな交換結合磁界を得ることが可能である。

【０２９９】よって一つの製法としては、成膜段階において前記反強磁性層４を上記の組成範囲内で形成し、さらに他の各層も成膜した後、熱処理を施せば良い。

【０３００】また本発明では、熱処理後において、反強磁性層４と固定磁性層３との界面、エクスチェンジバイアス層１６とフリー磁性層１との界面、エクスチェンジバイアス層２１と磁気抵抗層２０との界面、及びシードレイヤ２２が形成される場合には、前記シードレイヤ２２と反強磁性層４との界面、及び前記シードレイヤ２２とエクスチェンジバイアス層１６，２１との界面の少なくとも一部は非整合状態であることが好ましいが、前記非整合状態は成膜段階から保たれていることが好ましい。成膜段階において前記界面が整合状態であると、熱処理を施しても前記反強磁性層４等は適切な規則変態を起し難いと考えられるからである。

【０３０１】成膜段階において前記界面を非整合状態としておくためには、前記反強磁性層４等を例えば以下のような方法で形成することが好ましい。

【０３０２】図８は、図１に示す積層膜の各層を成膜した状態を示す模式図である。図８に示すように、下地層６上にシードレイヤ２２を形成した後、前記反強磁性層４を３層膜で形成する。前記反強磁性層４を構成する第１の反強磁性層２３、第２の反強磁性層２４、及び第３の反強磁性層２５は上記したＸ－Ｍｎ合金、Ｘ－Ｍｎ－Ｘ′合金で形成される。

【０３０３】ただし成膜段階において、第１及び第３の反強磁性層２３，２５を構成する元素Ｘあるいは元素Ｘ＋Ｘ′の組成比を、第２の反強磁性層２４の元素Ｘあるいは元素Ｘ＋Ｘ′の組成比よりも多くする。

【０３０４】また前記第１の反強磁性層２３と第３の反強磁性層２５との間に形成される第２の反強磁性層２４は、熱処理によって不規則格子から規則格子に変態しやすい理想的な組成に近い反強磁性材料で形成される。

【０３０５】このように第１の反強磁性層２３及び第３の反強磁性層２５の元素Ｘあるいは元素Ｘ＋Ｘ′の組成比を、第２の反強磁性層２４の元素Ｘあるいは元素Ｘ＋Ｘ′の組成比よりも大きくするのは、熱処理を施したときに、反強磁性層４が不規則格子から規則格子への変態をしやすくするため、各界面において、前記固定磁性層３及びシードレイヤ２２の結晶構造等に拘束されないようにする必要があるからである。

【０３０６】前記第１の反強磁性層２３及び第３の反強磁性層２５の元素Ｘあるいは元素Ｘ＋Ｘ′の組成比は５３（ａｔ％）以上６５（ａｔ％）以下であることが好ましく、より好ましくは５５（ａｔ％）以上６０（ａｔ％）以下である。また前記第１の反強磁性層２３及び第３の反強磁性層２５の膜厚は３Å以上３０Å以下であることが好ましい。例えば図８の場合では、前記第１及び第３の反強磁性層２３，２５をそれぞれ１０Å程度で形成している。

【０３０７】前記第２の反強磁性層２４の元素Ｘあるい

は元素X＋X′の組成比は、４４（ａｔ％）以上５７（ａｔ％）以下で形成される。好ましくは、４６（ａｔ％）以上５５（ａｔ％）以下である。元素Xあるいは元素X＋X′の組成比がこの範囲内で形成されると、熱処理を施すことによって前記第２の反強磁性層２４は不規則格子から規則格子へ変態しやすくなる。なお前記第２の反強磁性層２４の膜厚は７０Å以上であることが好ましい。なお図８に示す実施例の場合には、前記第２の反強磁性層２４の膜厚を１００Å程度で形成している。

【０３０８】また上記した各反強磁性層２３，２４，２５をスパッタ法で形成することが好ましい。なおこのとき、第１及び第３の反強磁性層２３，２５を、第２の反強磁性層２４よりも低いスパッタガス圧で形成することが好ましい。これにより、前記第１及び第３の反強磁性層２３，２５の元素Xあるいは元素X＋X′の組成比を、第２の反強磁性層２４の元素Xあるいは元素X＋X′の組成比よりも大きくすることが可能である。

【０３０９】あるいは本発明では、成膜段階（熱処理前）において前記反強磁性層４を上記した３層膜で形成せず、以下の方法によって前記反強磁性層４を単一層で形成した場合でも、膜厚方向に元素Xあるいは元素X＋X′の組成比（原子％）を適切に変化させて形成することが可能である。

【０３１０】まず元素XとMnとを含有する反強磁性材料、あるいは元素XとX′とMnとで形成されたターゲットを用いてスパッタによって反強磁性層４を形成する際に、シードレイヤ２２から離れるにしたがって徐々にスパッタガス圧を高くして反強磁性層４を成膜していき、前記反強磁性層４を半分程度成膜した段階で、今度は前記スパッタガス圧を徐々に低くして残りの反強磁性層４を成膜するのである。

【０３１１】この方法によれば、元素Xあるいは元素X＋X′の組成比（原子％）は、シードレイヤ２２との界面から前記反強磁性層４の膜厚の中央付近にかけて徐々に低くなっていき、前記組成比（原子％）は、前記中央付近から前記固定磁性層３との界面にかけて徐々に高くなる。

【０３１２】このため元素Xあるいは元素X＋X′の組成比（原子％）は、シードレイヤ２２及び固定磁性層３との界面近傍において最も大きく、膜厚のほぼ中央付近で最も低くなる反強磁性層４を形成することが可能になる。

【０３１３】なお前記固定磁性層３との界面近傍及びシードレイヤ２２との界面近傍で、前記反強磁性層４を構成する全元素の組成比を１００ａｔ％としたときに、元素Xあるいは元素X＋X′の組成比を、５３ａｔ％以上６５ａｔ％以下にすることが好ましく、より好ましくは５５ａｔ％以上６０ａｔ％以下である。

【０３１４】また反強磁性層４の膜厚方向の中央付近で、前記元素Xあるいは元素X＋X′の組成比を４４（ａｔ％）以上５７（ａｔ％）以下とすることが好ましく、より好ましくは４６（ａｔ％）以上５５（ａｔ％）以下である。また前記反強磁性層４の膜厚を７６Å以上で形成することが好ましい。

【０３１５】図９は、図８に示す積層膜に対し熱処理を施した後の状態を示すスピンバルブ型薄膜素子の模式図である。

【０３１６】本発明では、上記のように前記シードレイヤ２２及び固定磁性層３と接する側に、元素Xあるいは元素X＋X′の組成比が多い第１及び第３の反強磁性層２３，２５を形成し、しかも前記第１及び第３の反強磁性層２３，２５間に、熱処理によって適切に不規則格子から規則格子に変態しやすい組成で形成された第２の反強磁性層２４を設けているので、熱処理によって前記第２の反強磁性層２４の部分で変態が進むと同時に、第１及び第３の反強磁性層２３，２５と第２の反強磁性層２４間で組成拡散が起こると考えられ、したがって前記第１及び第３の反強磁性層２３，２５の部分でも、シードレイヤ２２及び固定磁性層３との界面で適切に非整合状態を維持しながら、不規則格子から規則格子への変態が起こり、反強磁性層４全体で適切な変態を起すことができる。

【０３１７】そして熱処理後におけるスピンバルブ型薄膜素子では、前記反強磁性層４と固定磁性層３は膜面と平行な方向に同じ等価な結晶面が優先配向し、しかも前記結晶面内に存在する、ある同じ等価な結晶軸の少なくとも一部が、反強磁性層４と固定磁性層３とで互いに異なる方向を向いているのである。

【０３１８】また前記反強磁性層４と固定磁性層３とを膜厚と平行な方向（図示Z方向）から断面としてみたときに、前記反強磁性層４の結晶粒界と前記固定磁性層３の結晶粒界は界面の少なくとも一部において不連続な状態になっている。

【０３１９】また本発明では、前記反強磁性層４の下にシードレイヤが形成されているため、前記反強磁性層は前記界面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向し、しかも前記反強磁性層４には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となっている。なお前記双晶境界と界面間の内角は６８°以上で７６°以下であることが好ましい。さらに前記固定磁性層３も[１１１]面として表される等価な結晶面が優先配向していることが好ましい。

【０３２０】なお熱処理後における反強磁性層４には、シードレイヤ２２及び固定磁性層３に向かうにしたがって、Mnに対する元素Xあるいは元素X＋X′の原子％の比率が、増加する領域が存在すると考えられる。

【０３２１】図２に示すスピンバルブ型薄膜素子の場合では、反強磁性層４を上記した３層膜で形成してもよいが、例えば固定磁性層３側に接する第１の反強磁性層２

３と保護層７側に接する第２の反強磁性層２４の２層構造で形成してもよい。図２では図１のようにシードレイヤ２２が無いからである。

【０３２２】なお上記のように反強磁性層４を２層膜で形成した場合には、熱処理後における反強磁性層４には、固定磁性層３に向かうにしたがって、Ｍｎに対する元素Ｘあるいは元素Ｘ＋Ｘ′の原子％の比率が増加する領域が存在するものと考えられる。

【０３２３】また図３のスピンバルブ型薄膜素子の場合では、エクスチェンジバイアス層１６を図２の場合と同様に２層膜で形成する。第１の反強磁性層２３はフリー磁性層１側に接して形成し、前記フリー磁性層１から離れた側に第２の反強磁性層２４を形成する。

【０３２４】また図３に示す反強磁性層４を図１の場合と同様に３層膜で形成する。熱処理を施すことにより、前記エクスチェンジバイアス層１６及び反強磁性層４は適切な規則変態を起し、大きな交換結合磁界を得ることが可能である。

【０３２５】熱処理後における前記エクスチェンジバイアス層１６には、フリー磁性層１に向かうにしたがって、Ｍｎに対する元素Ｘあるいは元素Ｘ＋Ｘ′の原子％の比率が増加する領域が存在するものと考えられる。

【０３２６】また熱処理後における前記反強磁性層４には、固定磁性層３及びシードレイヤ２２に向かうにしたがってＭｎに対する元素Ｘあるいは元素Ｘ＋Ｘ′の原子％の比率が増加する領域が存在するものと考えられる。

【０３２７】また図４に示すスピンバルブ型薄膜素子の製造方法では、反強磁性層４を図２の場合と同様に２層膜で形成する。第１の反強磁性層２３は固定磁性層３側に接して形成し、前記固定磁性層３から離れた側に第２の反強磁性層２４を形成する。

【０３２８】またエクスチェンジバイアス層１６を図１の反強磁性層４の場合と同様に３層膜で形成する。熱処理を施すことにより、前記エクスチェンジバイアス層１６及び反強磁性層４は適切な規則変態を起し、大きな交換結合磁界を得ることが可能である。

【０３２９】熱処理後における前記エクスチェンジバイアス層１６には、フリー磁性層１及びシードレイヤ２２に向かうにしたがって、Ｍｎに対する元素Ｘあるいは元素Ｘ＋Ｘ′の原子％の比率が増加する領域が存在するものと考えられる。

【０３３０】また熱処理後における前記反強磁性層４には、固定磁性層３に向かうにしたがって、Ｍｎに対する元素Ｘあるいは元素Ｘ＋Ｘ′の原子％の比率が増加する領域が存在するものと考えられる。

【０３３１】図５に示すデュアルスピンバルブ型薄膜素子の製造方法では図１０に示すように、フリー磁性層１よりも下側に位置する反強磁性層４を、第１の反強磁性層２３、第２の反強磁性層２４、及び第３の反強磁性層２５の３層膜で形成し、フリー磁性層１よりも上側に位置する反強磁性層４を、第１の反強磁性層１４及び第２の反強磁性層１５の２層膜で形成する。

【０３３２】前記第１の反強磁性層２３、第２の反強磁性層２４、及び第３の反強磁性層２５の膜厚、及び組成に関しては図１で説明したものと同じである。

【０３３３】図１０に示すように成膜した後、熱処理を施す。その状態は図１１に表されている。図１１では、フリー磁性層１よりも下側に形成されている反強磁性層４を構成する３層膜が組成拡散を起し、熱処理後における前記反強磁性層４には、固定磁性層３及びシードレイヤ２２に向かうにしたがって、Ｍｎに対する元素Ｘあるいは元素Ｘ＋Ｘ′の原子％の比率が増加する領域が存在するものと考えられる。

【０３３４】またフリー磁性層１よりも上側に形成された反強磁性層４を構成する２層膜もまた組成拡散を起し、熱処理後における前記反強磁性層４には、固定磁性層３に向かうにしたがって、Ｍｎに対する元素Ｘあるいは元素Ｘ＋Ｘ′の原子％の比率が増加する領域が存在するものと考えられる。

【０３３５】次に図６に示すＡＭＲ型薄膜素子の製造方法では、エクスチェンジバイアス層２１を図１０に示すフリー磁性層１よりも図示上側に形成された反強磁性層４と同様に２層膜で形成する。前記エクスチェンジバイアス層２１は、磁気抵抗層２０と接する第１の反強磁性層１４と前記磁気抵抗層２０から離れた側に形成される第２の反強磁性層１５とで形成する。

【０３３６】熱処理を施すと、前記エクスチェンジバイアス層２１は適切な規則変態を起し、前記エクスチェンジバイアス層２１と磁気抵抗層２０との間で大きな交換結合磁界が発生する。

【０３３７】そして熱処理後における前記エクスチェンジバイアス層２１には、磁気抵抗層２０に向かうにしたがって、Ｍｎに対する元素Ｘあるいは元素Ｘ＋Ｘ′の原子％の比率が増加する領域が存在するものと考えられる。

【０３３８】また図７に示すＡＭＲ型薄膜素子の製造方法では、エクスチェンジバイアス層２１を図８に示す反強磁性層４と同様に３層膜で形成する。前記エクスチェンジバイアス層２１は、磁気抵抗層２０に接する第１の反強磁性層２３と、シードレイヤ２２に接する第３の反強磁性層２５と、前記第１及び第３の反強磁性層２３，２５の間に形成される第２の反強磁性層２４で形成する。

【０３３９】熱処理を施すと、前記エクスチェンジバイアス層２１は適切な規則変態を起し、前記エクスチェンジバイアス層２１と磁気抵抗層２０との間で大きな交換結合磁界が発生する。

【０３４０】そして熱処理後における前記エクスチェンジバイアス層２１には、磁気抵抗層２０及びシードレイヤ２２に向かうにしたがって、Ｍｎに対する元素Ｘある

いは元素X＋X′の原子%の比率が増加する領域が存在するものと考えられる。

【0341】図12は、図1から図11に示す磁気抵抗効果素子が形成された読み取りヘッドの構造を記録媒体との対向面側から見た断面図である。

【0342】符号40は、例えばNiFe合金などで形成された下部シールド層であり、この下部シールド層40の上に下部ギャップ層41が形成されている。また下部ギャップ層41の上には、図1ないし図7に示す磁気抵抗効果素子42が形成されており、さらに前記磁気抵抗効果素子42の上には、上部ギャップ層43が形成され、前記上部ギャップ層43の上には、NiFe合金などで形成された上部シールド層44が形成されている。

【0343】前記下部ギャップ層41及び上部ギャップ層43は、例えばSiO_2やAl_2O_3（アルミナ）などの絶縁材料によって形成されている。図12に示すように、下部ギャップ層41から上部ギャップ層43までの長さがギャップ長Glであり、このギャップ長Glが小さいほど高記録密度化に対応できるものとなっている。

【0344】本発明では反強磁性層4の膜厚を小さくしてもなお大きな交換結合磁界を発生させることができる。よって磁気抵抗効果素子の膜厚を従来に比べて小さくすることができ、狭ギャップ化により高記録密度化に対応可能な薄膜磁気ヘッドを製造することが可能になっている。

【0345】なお本発明では、図1、図3、図4、図5及び図7において反強磁性層4（またはエクスチェンジバイアス層16あるいは磁気抵抗層20）の下側にシードレイヤ22を形成した実施例を載せたが、この形態に限定するものではない。

【0346】また本発明では、膜厚方向と平行な方向に切断した切断面において、反強磁性層4の結晶粒界と強磁性層の結晶粒界とが界面の少なくとも一部で不連続な状態となっているが、この場合、前記反強磁性層及び強磁性層の結晶配向は、膜面と平行な方向に異なる結晶面が優先配向していてもかまわない。このような場合でも反強磁性層は熱処理によって適切な規則変態を起し大きな交換結合磁界を得ることが可能である。

【0347】

【実施例】本発明では、以下に記載する膜構成のスピンバルブ膜を形成し、反強磁性層を構成するPtMn合金膜のPt量を変化させながら、前記Pt量と交換結合磁界（Hex）との関係を調べた。

【0348】膜構成は下から、Si基板／アルミナ／下地層：Ta（3nm）／シードレイヤ：NiFe（3nm）／反強磁性層：Pt_xMn_{100-x}（15nm）／固定磁性層：［Co（1.5nm）／Ru（0.8nm）／Co（2.5nm）］／非磁性中間層：Cu（2.3nm）／フリー磁性層：［Co（1nm）／NiFe（3nm）］／バックド層：Cu（1.5nm）／保護層：Ta（3nm）であり、各層に記載された括弧書きの数値は膜厚を示している。

【0349】前記反強磁性層及び固定磁性層をDCマグネトロンスパッタ法で成膜した。また前記反強磁性層及び固定磁性層を形成するとき、Arガス圧を1～3mTorrとした。また前記反強磁性層を成膜するとき、基板とターゲット間の距離を70～80mmとした。上記膜構成のスピンバルブ膜を成膜した後、200℃以上で2時間以上の熱処理を施し、交換結合磁界を測定した。その実験結果を図13に示す。

【0350】図13に示すように、Pt量Xが約50（at%）～55（at%）程度まで増加すると、交換結合磁界（Hex）も増加することがわかる。また前記Pt量Xが約55（at%）以上になると交換結合磁界は徐々に減少することがわかる。

【0351】本発明では、交換結合磁界が1.58×10^4（A／m）以上得られる場合を好ましいPt量とし、図13に示す実験結果から好ましいPt量を45（at%）以上60（at%）以下と設定した。

【0352】また本発明では交換結合磁界が7.9×10^4（A／m）以上得られる場合をより好ましいPt量とし、図13に示す実験結果からより好ましいPt量を49（at%）以上56.5（at%）以下と設定した。

【0353】上記のようにPt量によって交換結合磁界の大きさに変化が現れるのは、Pt量を変化させることによって反強磁性層と強磁性層（固定磁性層）との界面の状態が変化するためであると考えられる。

【0354】ここでPt量は多くなればなるほど反強磁性層の格子定数は大きくなることがわかっている。このためPt量を多くすることによって反強磁性層と強磁性層との格子定数の差を広げることができ、前記反強磁性層と強磁性層との界面を非整合状態にしやすくできる。

【0355】一方、上記した膜構成のように反強磁性層の下側にシードレイヤを形成することによって前記シードレイヤ上に形成される反強磁性層等の各層の結晶配向を、前記シードレイヤと同様に膜面と平行な方向に[111]面を優先配向させやすくなる。

【0356】またPt量は多ければ多いほど良いわけではない。Pt量を多くしすぎると前記反強磁性層は熱処理を施しても適切な規則変態を起すことができないからである。

【0357】本発明では、反強磁性層の下側にシードレイヤを敷いたこと、及び反強磁性層を構成するPt量を規則変態を起しやすく且つ強磁性層との界面を非整合状態に保ちやすい組成で形成し、さらに上記した成膜条件を適切に制御するなどによって、熱処理を施すと前記反強磁性層は、強磁性層との界面で非整合状態を保ちながら適切な規則変態を起し、熱処理を施した後の状態では、前記反強磁性層と強磁性層は膜面と平行な方向に同

じ等価な結晶面が優先配向し、且つ前記結晶面内に存在する、ある同じ等価な結晶軸の方向の少なくとも一部が前記反強磁性層と強磁性層とで互いに異なる方向を向く結晶配向となっているのである。

【０３５８】また前記反強磁性層と強磁性層とを膜厚と平行な方向から切断した切断面を観測すると、前記反強磁性層の結晶粒界と強磁性層の結晶粒界とが、前記反強磁性層と強磁性層との界面の少なくとも一部で不連続な状態となっているのである。

【０３５９】また本発明では、前記反強磁性層と固定磁性層とが前記界面と平行な方向に代表的に[１１１]面として表される等価な結晶面が優先配向し、しかも前記反強磁性層４には少なくとも一部に双晶が形成され、一部の前記双晶の双晶境界は、前記界面と非平行となるのである。

【０３６０】

【発明の効果】以上詳述したように本発明における交換結合膜では、前記交換結合膜を膜厚方向と平行な切断面に現われる前記反強磁性層に形成された結晶粒界と、強磁性層に形成された結晶粒界とが前記界面の少なくとも一部で不連続となっている。

【０３６１】また本発明では、前記反強磁性層は前記界面と平行な方向に[１１１]面として表される等価な結晶面が優先配向し、前記反強磁性層には少なくとも一部に双晶が形成され、前記双晶の少なくとも一部の前記双晶の双晶境界は、前記界面と非平行に形成されていることを特徴とするものである。なお前記双晶境界と前記界面間の内角は、６８°以上で７６°以下であることが好ましい。

【０３６２】上記した膜構造が熱処理後によって得られた場合、前記反強磁性層は熱処理により適切に不規則格子から規則格子に変態しており、大きな交換結合磁界を得ることができる。

【０３６３】上記した交換結合膜は様々な磁気抵抗効果素子に適用することができ、前記交換結合膜を有する磁気抵抗効果素子であると、今後の高記録密度化に適切に対応することが可能になる。

【図面の簡単な説明】

【図１】本発明の第１実施形態のシングルスピンバルブ型磁気抵抗効果素子の構造をＡＢＳ面側から見た断面図、

【図２】本発明の第２実施形態のシングルスピンバルブ型磁気抵抗効果素子の構造をＡＢＳ面側から見た断面図、

【図３】本発明の第３実施形態のシングルスピンバルブ型磁気抵抗効果素子の構造をＡＢＳ面側から見た断面図、

【図４】本発明の第４実施形態のシングルスピンバルブ型磁気抵抗効果素子の構造をＡＢＳ面側から見た断面図、

【図５】本発明の第５実施形態のデュアルスピンバルブ型磁気抵抗効果素子の構造をＡＢＳ面側から見た断面図、

【図６】本発明の第６実施形態のＡＭＲ型磁気抵抗効果素子の構造をＡＢＳ面側から見た断面図、

【図７】本発明の第７実施形態のＡＭＲ型磁気抵抗効果素子の構造をＡＢＳ面側から見た断面図、

【図８】図１に示す磁気抵抗効果素子の成膜段階の状態を示す模式図、

【図９】図８に示す積層膜に熱処理を施した後の前記積層膜の構造を示す模式図、

【図１０】図５に示す磁気抵抗効果素子の成膜段階の状態を示す模式図、

【図１１】図１０に示す積層膜に熱処理を施した後の前記積層膜の構造を示す模式図、

【図１２】本発明における薄膜磁気ヘッド（再生ヘッド）の構造示す部分断面図、

【図１３】反強磁性層（ＰｔＭｎ合金膜）のＰｔ量を変化させた場合における、前記Ｐｔ量と交換結合磁界（Ｈｅｘ）との関係を示すグラフ、

【図１４】本発明における交換結合膜の反強磁性層と強磁性層との結晶配向を模式図的に示した図、

【図１５】比較例における交換結合膜の反強磁性層と強磁性層との結晶配向を模式図的に示した図、

【図１６】本発明におけるスピンバルブ膜の膜面と平行方向からの透過電子線回折像、

【図１７】比較例におけるスピンバルブ膜の膜面と平行方向からの透過電子線回折像、

【図１８】図１６に示す透過電子線回折像の部分模式図、

【図１９】図１７に示す透過電子線回折像の部分模式図、

【図２０】本発明における反強磁性層の膜面と垂直方向からの透過電子線回折像の模式図、

【図２１】本発明における強磁性層の膜面と垂直方向からの透過電子線回折像の模式図、

【図２２】図２０及び２１の透過電子線回折像を重ねあわせた模式図、

【図２３】比較例における反強磁性層の膜面と垂直方向からの透過電子線回折像の模式図、

【図２４】比較例における強磁性層の膜面と垂直方向からの透過電子線回折像の模式図、

【図２５】図２３及び２４の透過電子線回折像を重ねあわせた模式図、

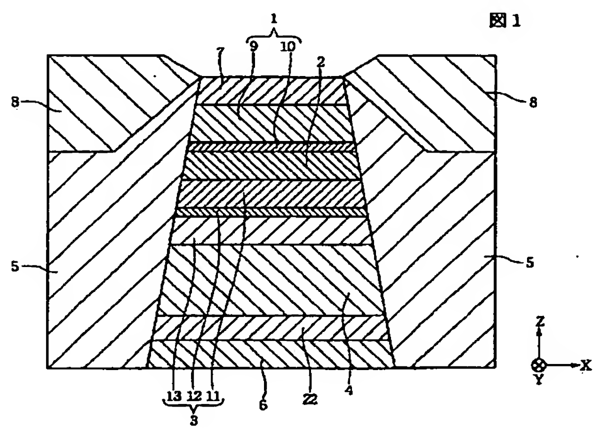
【図２６】本発明におけるスピンバルブ型薄膜素子を膜厚と平行な方向から切断した際の前記切断面の透過電子顕微鏡写真、

【図２７】比較例におけるスピンバルブ型薄膜素子を膜厚と平行な方向から切断した際の前記切断面の透過電子顕微鏡写真、

【図２８】図２６に示す透過電子顕微鏡写真の部分模式図、
【図２９】図２７に示す透過電子顕微鏡写真の部分模式図、
【図３０】本発明における別の実施例のスピンバルブ型薄膜素子を膜厚と平行な方向から切断した際の前記切断面の透過電子顕微鏡写真、
【図３１】図３０に示す透過電子顕微鏡写真の部分模式図、
【符号の説明】
1　フリー磁性層
2　非磁性中間層
3　固定磁性層（強磁性層）
4　反強磁性層
5　ハードバイアス層
6　下地層
7　保護層
8　導電層
１４、２３　第１の反強磁性層
１５、２４　第２の反強磁性層
１６、２１　エクスチェンジバイアス層
１７、２６　絶縁層
１８　軟磁性層（ＳＡＬ層）
１９　非磁性層（ＳＨＵＮＴ層）
２０　磁気抵抗層（ＭＲ層）
２２　シードレイヤ
２５　第３の反強磁性層
４２　磁気抵抗効果素子

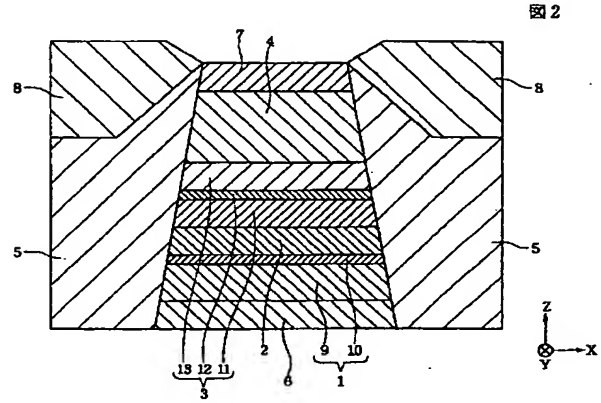
【図１】

図1



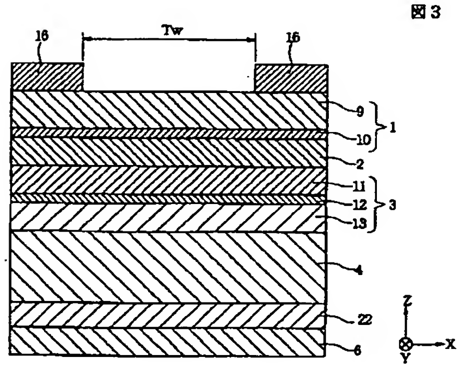
【図２】

図2



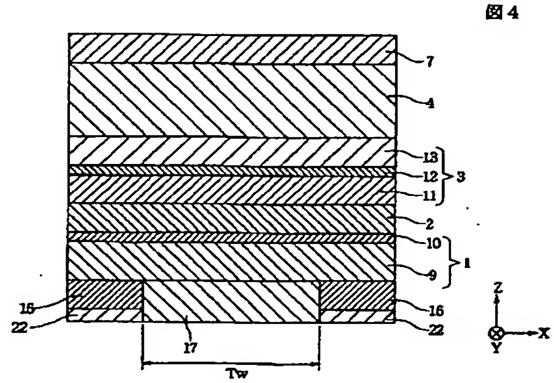
【図３】

図3



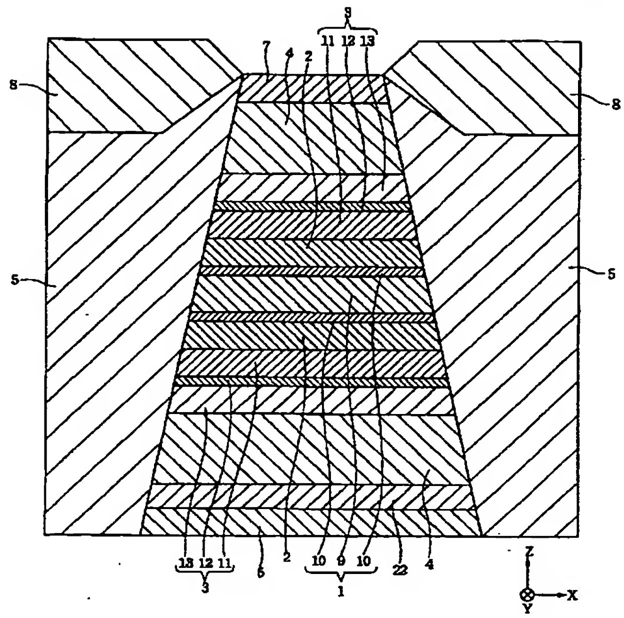
【図４】

図4



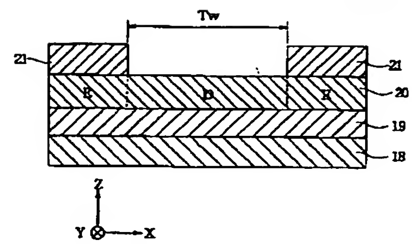
【図5】

図5



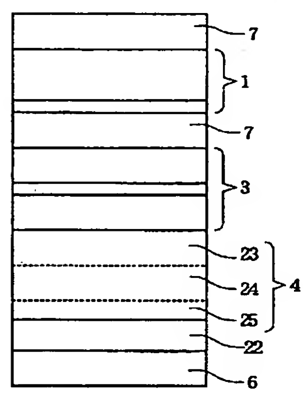
【図6】

図6



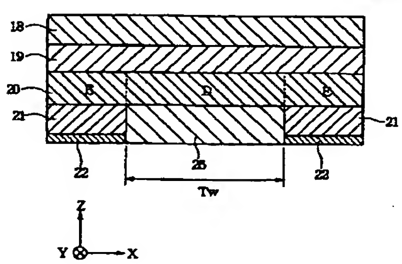
【図9】

図9



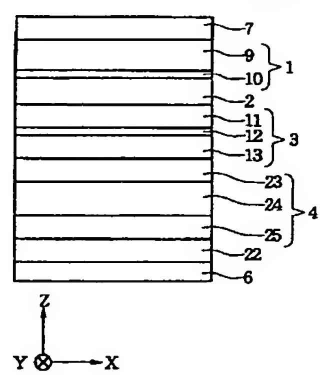
【図7】

図7



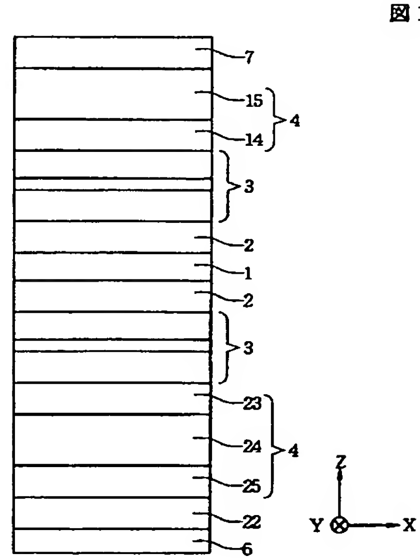
【図8】

図8



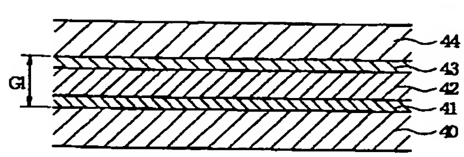
【図10】

図10



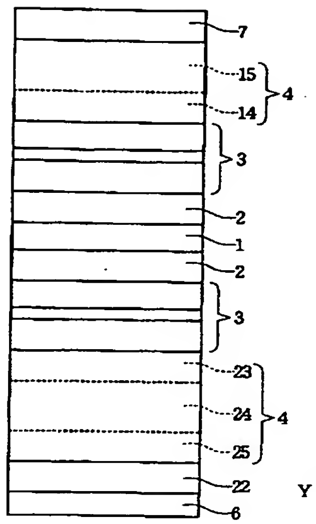
【図12】

図12



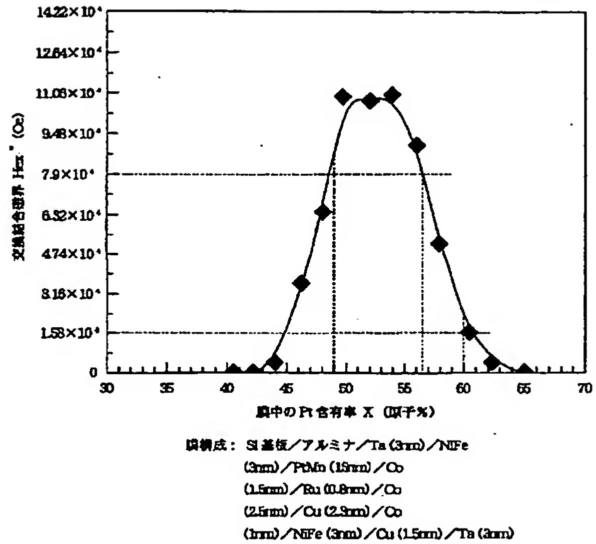
【図11】

図11



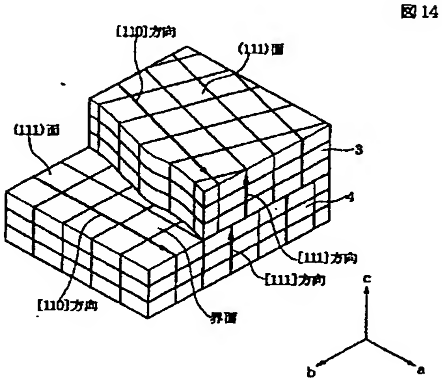
【図13】

図13



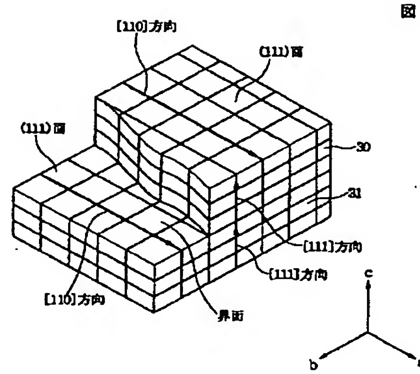
【図14】

図14



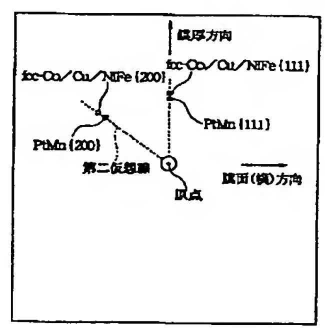
【図15】

図15



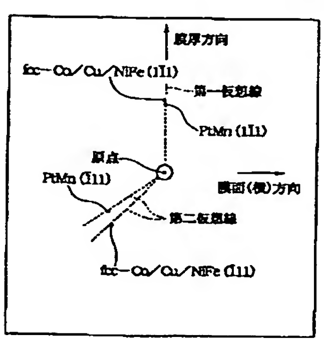
【図19】

図19



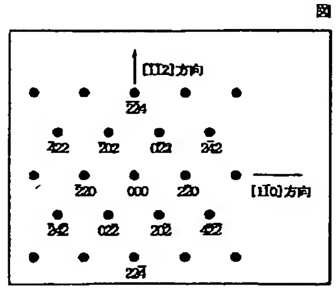
【図18】

図18



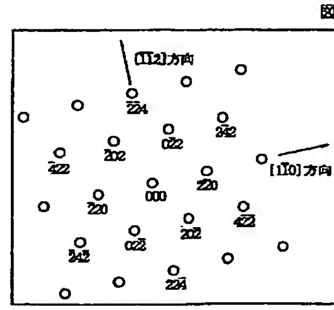
【図20】

図20



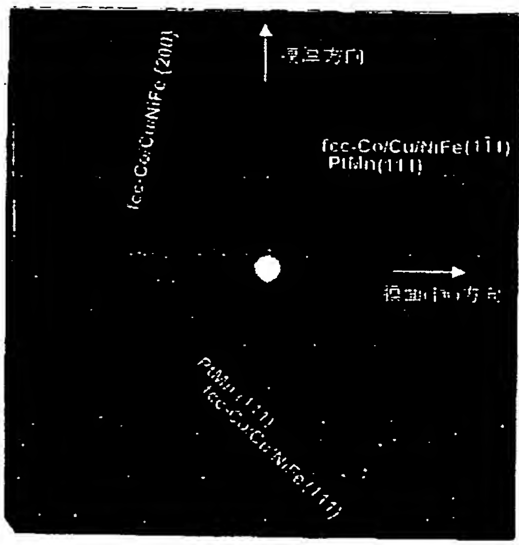
【図21】

図21



【図１６】

図 16

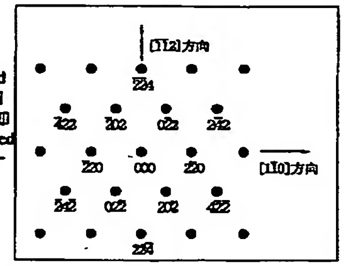


PtMn及びfcc-Co(Pin層)を含むPin/Cu/Free/Backed層部(Co/Ru/Co/Cu/Co/NiFe/Cu部)の{111}面の回折斑点は膜厚方向の同一直線上に乗っている。即ちPtMnの{111}面の法線方向とPin/Cu/Free/Backed層部の{111}面の法線方向はともに膜厚方向に一致している。

しかし、上記とは別の等価な{111}面、即ち、例えば上記の膜面と平行な{111}面を具体的に(1$\bar{1}$1)面と指数付けした場合、これと70.5°の角度をなし、膜面と平行な関係にない($\bar{1}$11)面の回折斑点に着目すると、PtMnとPin/Cu/Free/Backed層部のそれぞれの($\bar{1}$11)面の回折斑点は回折図形中心(電子線中心)を通る同一直線上にはない。即ち膜面平行方向以外の結晶面についてはPtMnとPin層の結晶面が平行関係を持っていない。

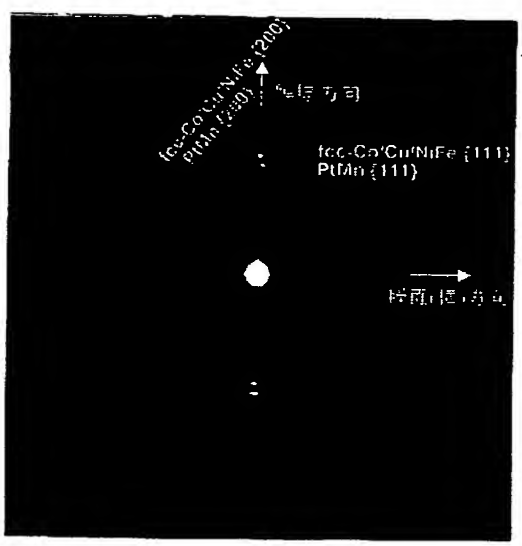
【図２３】

図 23



【図１７】

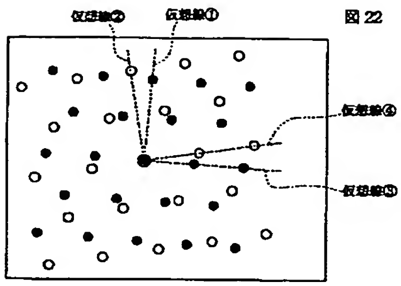
図 17



PtMn及びfcc-Co(Pin層)を含むPin/Cu/Free/Backed層部(Co/Ru/Co/Cu/Co/NiFe/Cu部)の{111}面の回折斑点が膜厚方向の同一直線上に乗っているばかりでなく、膜厚方向以外の方向にある{200}回折斑点も両者が中心を通る同一直線上に乗っている。これら以外の回折斑点についても全て同様であり、相似形の関係にあるPtMnとPin/Cu/Free/Backed層部の2つの回折図形を、方向を一致させて重ねた図形となっている。(PtMnの回折図形がPin/Cu/Free/Backed層部のそれの約9割縮小された形となっているのはPtMnの格子定数が約1割大きいからである。) 従って、PtMnとPin/Cu/Free/Backed層部は結晶学的に完全な整合関係、即ちエピタキシャルな関係にあることがわかる。

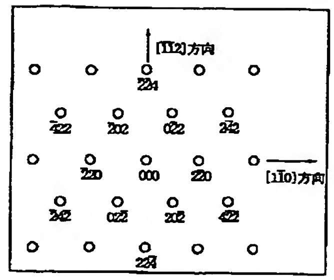
【図２２】

図 22



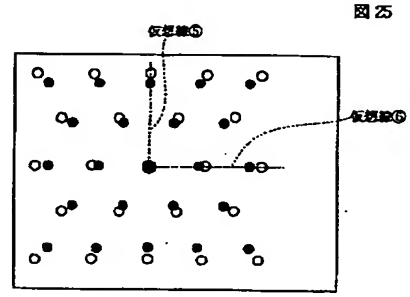
【図２４】

図 24



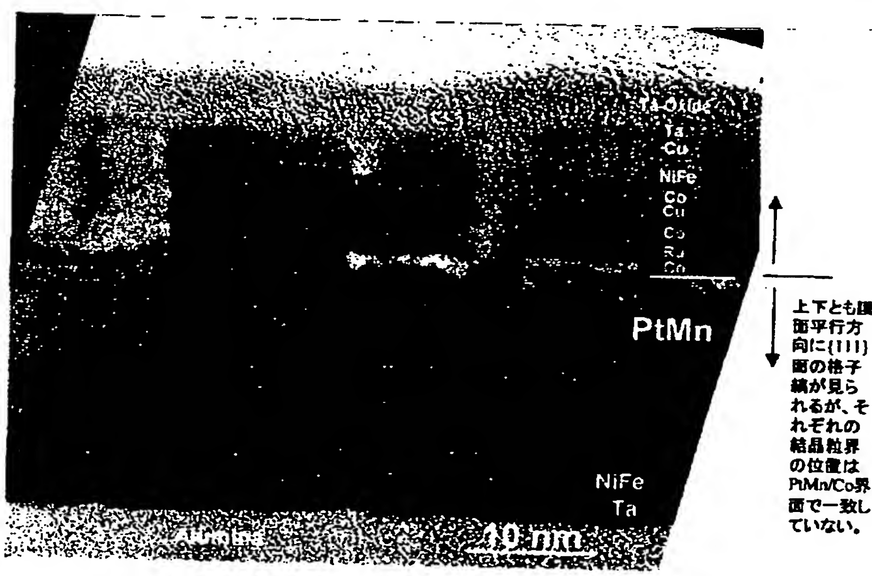
【図２５】

図 25



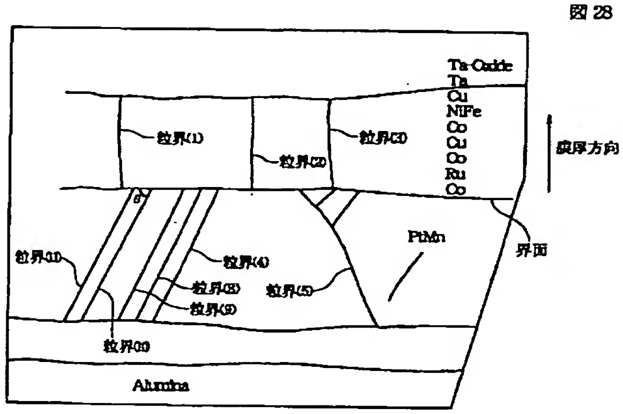
【図２６】

図 26



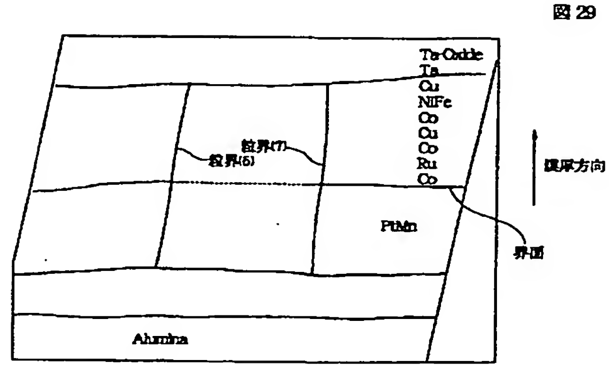
【図２８】

図 28



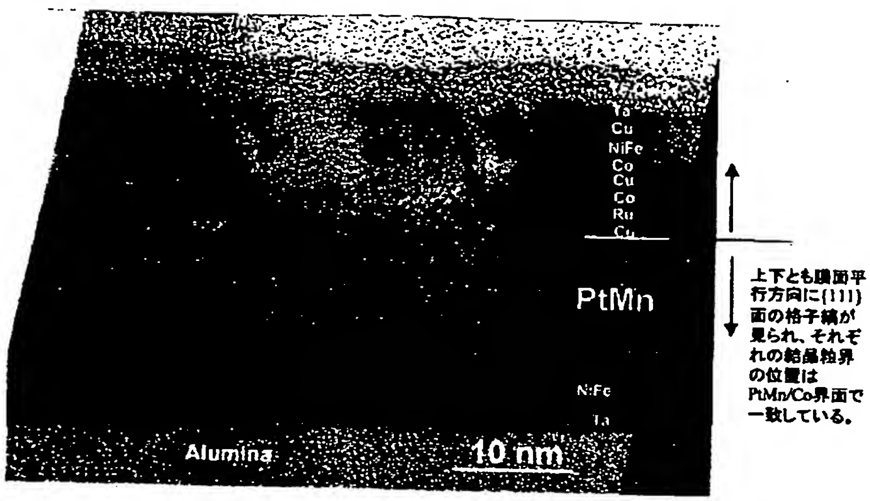
【図２９】

図 29



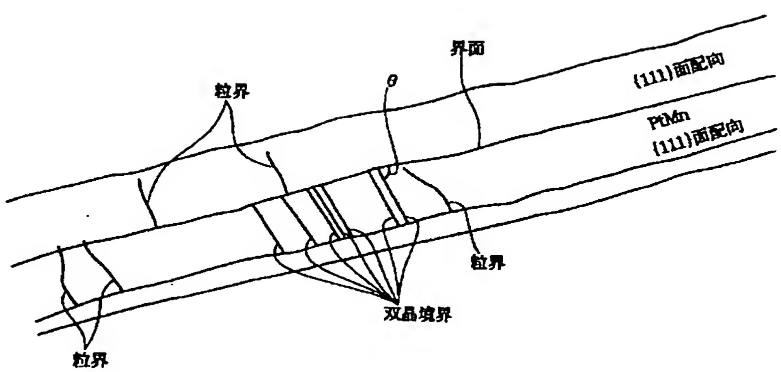
【図２７】

図 27



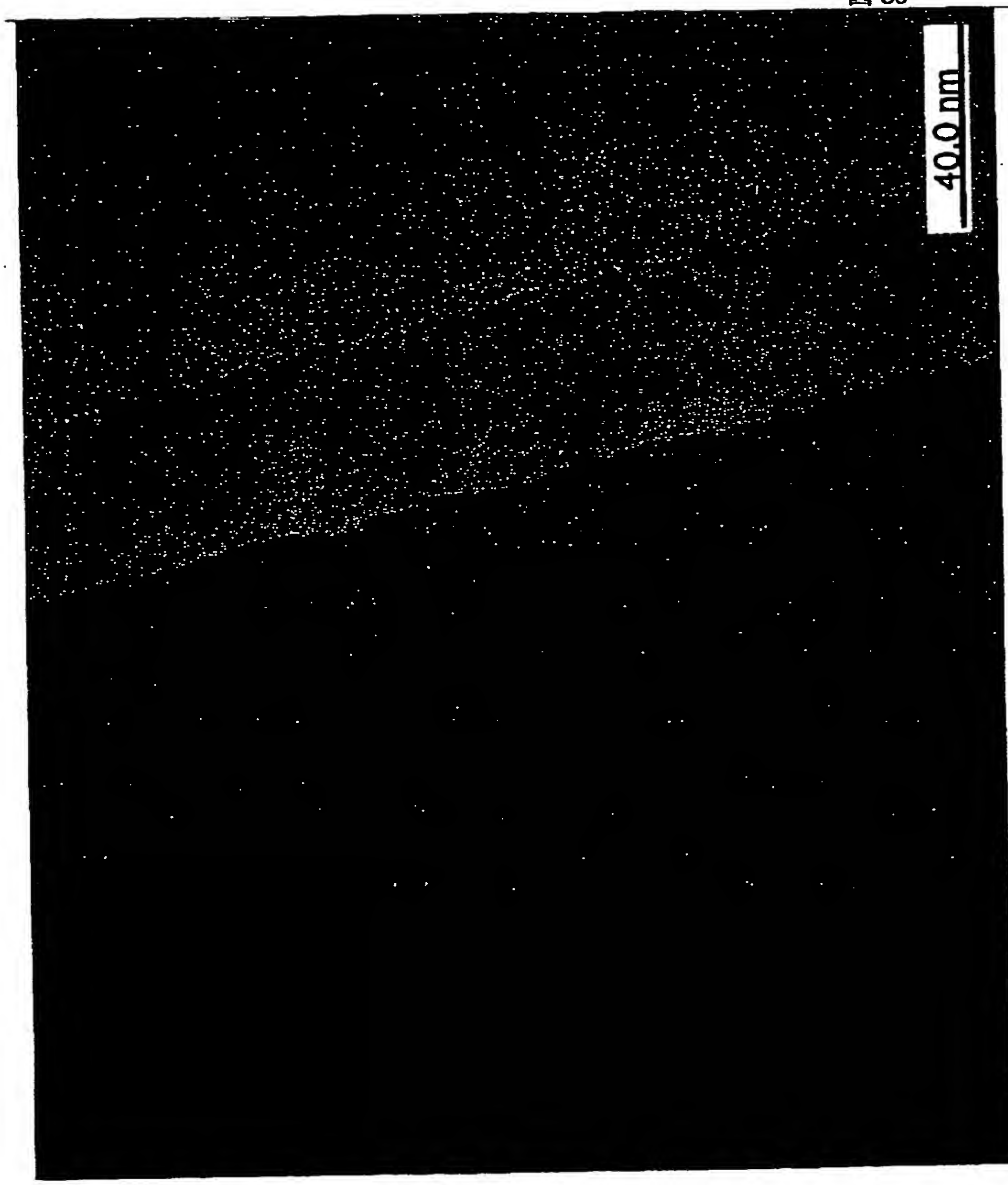
【図３１】

図 31



【図３０】

図 30



【手続補正書】

【提出日】平成１３年2月２７日（２００１．２．２７）

【手続補正１】

【補正対象書類名】明細書

【補正対象項目名】０３５１

【補正方法】変更

【補正内容】

【０３５１】本発明では、交換結合磁界が１．５８×１０^4（Ａ／ｍ）以上得られる場合を好ましいＰｔ量とし、図１３に示す実験結果から好ましいＰｔ量を４５（ａｔ％）以上６０（ａｔ％）以下と設定した。

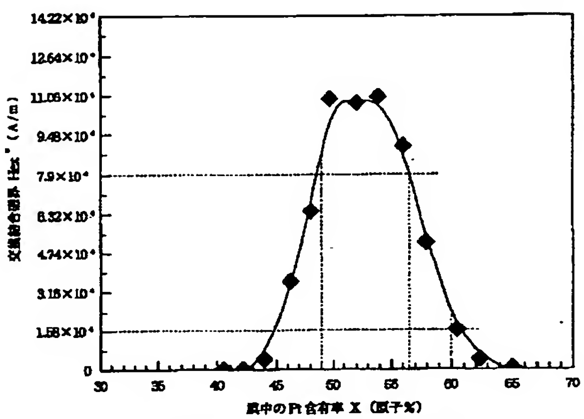
【手続補正２】

【補正対象書類名】明細書

【補正対象項目名】０３５２

【補正方法】変更
【補正内容】
【０３５２】また本発明では交換結合磁界が７．９×１０⁴（Ａ／ｍ）以上得られる場合をより好ましいＰｔ量とし、図１３に示す実験結果からより好ましいＰｔ量を４９（ａｔ％）以上５６．５（ａｔ％）以下と設定した。
【手続補正３】
【補正対象書類名】図面
【補正対象項目名】図１３
【補正方法】変更
【補正内容】
【図１３】

図 13



膜構成：Si基板／アルミナ／Ta (3nm)／NiFe (3nm)／PtMn (15nm)／Co (1.5nm)／Ru (0.8nm)／Co (2.5nm)／Cu (2.3nm)／Co (1nm)／NiFe (3nm)／Cu (1.5nm)／Ta (3nm)

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2002-094141
(43)Date of publication of application : 29.03.2002

(51)Int.Cl. H01L 43/08
G01R 33/09
G11B 5/39
H01F 10/16
H01F 10/32

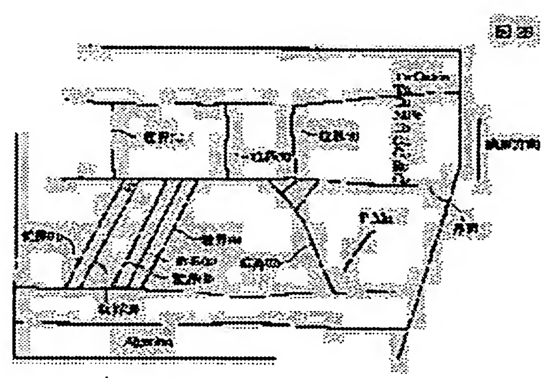
(21)Application number : 2000-366972
(22)Date of filing : 01.12.2000

(71)Applicant : ALPS ELECTRIC CO LTD
(72)Inventor : HASEGAWA NAOYA
SAITO MASAJI

(30)Priority
Priority number : 2000209462 Priority date : 11.07.2000 Priority country : JP

(54) EXCHANGE COUPLING FILM, MAGNETO-RESISTANCE EFFECT ELEMENT USING THE FILM AND THIN FILM MAGNETIC HEAD USING THE ELEMENT

(57)Abstract:
PROBLEM TO BE SOLVED: To overcome the problem of a prior art such that an exchange coupling magnetic field becomes small depending on the state of a grain boundary even when a PtMn alloy film is used as an antiferromagnetic layer while the PtMn alloy film is known as the antiferromagnetic material with excellent corrosion resistance.
SOLUTION: The grain boundary formed at the antiferromagnetic layer (PtMn alloy film) and the grain boundary formed at a ferromagnetic layer are turned to a non-continuous state at least at a part of a boundary. Thus, the antiferromagnetic layer is made to cause an appropriate regular transformation by providing thermal treatment, and the exchange coupling magnetic field larger than before can be obtained.



EGAL STATUS
[Date of request for examination] 28.02.2001
[Date of sending the examiner's decision of rejection]
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]
[Date of final disposal for application]
[Patent number]

[Date of registration]
[Number of appeal against examiner's decision of rejection]
[Date of requesting appeal against examiner's decision of rejection]
[Date of extinction of right]

* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] By the switched connection magnetic field which this invention consists of an antiferromagnetism layer and a ferromagnetic layer, and is generated in the interface of the aforementioned antiferromagnetism layer and a ferromagnetic layer The switched connection film with which the magnetization direction of the aforementioned ferromagnetic layer is fixed in the fixed direction is started. It is related with the switched connection film which enabled it to acquire the aforementioned large switched connection magnetic field especially and the magnetoresistance-effect element (a spin bulb type thin film, AMR element) using this switched connection film, and the thin film magnetic head which used the aforementioned magnetoresistance-effect element for the row.
[0002]
[Description of the Prior Art] A spin bulb type thin film is one sort using the huge magnetoresistance effect of a GMR (giant magnetoresistive) element, and detects the record magnetic field from record media, such as a hard disk.
[0003] This spin bulb type thin film has the point which was excellent in some -- also in a GMR element, structure is comparatively simple and, moreover, resistance changes by the weak magnetic field.
[0004] The aforementioned spin bulb type thin film is the simplest structure, and consists of an antiferromagnetism layer, a fixed magnetic layer, a nonmagnetic interlayer, and a free magnetic layer.
[0005] the exchange-anisotropy magnetic field which the aforementioned antiferromagnetism layer and a fixed magnetic layer touch, and it is formed, and is generated in the interface of the aforementioned antiferromagnetism layer and a fixed magnetic layer -- the magnetization direction of the aforementioned fixed magnetic layer -- the fixed direction -- single -- a magnetic domain -- it is-izing and fixed
[0006] Magnetization of a free magnetic layer is arranged in the magnetization direction of the aforementioned fixed magnetic layer, and the crossing direction by the bias layer formed in the both sides.
[0007] Although the Fe-Mn (iron-manganese) alloy film, the nickel-Mn (nickel-manganese) alloy film, or the Pt-Mn (platinum-manganese) alloy film is generally used for the aforementioned antiferromagnetism layer, also in this, especially the Pt-Mn alloy film has the point which was excellent in various [, such as blocking temperature being high and excelling in corrosion resistance moreover], and is in the limelight.
[0008]
[Problem(s) to be Solved by the Invention] By the way, it turns out that the switched connection magnetic field generated between the aforementioned antiferromagnetism layer and a fixed magnetic layer even if this invention persons use a PtMn alloy film for an antiferromagnetism layer is not greatly made according to conditions.
[0009] When a PtMn alloy film is used for the aforementioned antiferromagnetism layer, after carrying out the laminating of the aforementioned antiferromagnetism layer and the fixed magnetic layer, by performing heat treatment, the aforementioned antiferromagnetism layer can be made to be able to metamorphose into a superlattice from an irregular grid, and a switched connection magnetic field can be produced by this.
[0010] However, when the atom of the antiferromagnetism material which constitutes an antiferromagnetism layer from an interface of the aforementioned antiferromagnetism layer and a ferromagnetic layer, and the atom of the soft magnetic materials which constitute a fixed magnetic layer had changed into the so-called adjustment state corresponding to 1 to 1, the aforementioned

antiferromagnetism layer could not cause the above-mentioned rule transformation appropriately, but it turns out that a big switched connection magnetic field must have been produced.
[0011] this invention is for solving the above-mentioned conventional technical problem, and when the antiferromagnetism material containing Elements X (X is platinum group metals) and Mn is used as an antiferromagnetism layer, it relates to the switched connection film which enabled it to generate a large exchange-anisotropy magnetic field and the magnetoresistance-effect element using this switched connection film, and the thin film magnetic head which used the aforementioned magnetoresistance-effect element for the row.
[0012]
[Means for Solving the Problem] In the switched connection film with which an antiferromagnetism layer and a ferromagnetic layer touch, and are formed, a switched connection magnetic field generates this invention in the interface of the aforementioned antiferromagnetism layer and a ferromagnetic layer, and the magnetization direction of the aforementioned ferromagnetic layer is carried out in the fixed direction The aforementioned antiferromagnetism layer is formed with the antiferromagnetism material containing Elements X (however, X is one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn. It is characterized by the grain boundary formed in the aforementioned antiferromagnetism layer which appears in a cutting plane parallel to the direction of thickness in the aforementioned switched connection film and the grain boundary formed in the ferromagnetic layer being discontinuous at a part of aforementioned interface [at least].
[0013] The aforementioned grain boundary said by this invention here is a boundary where the crystal orientation from which two crystal grain differs is maintained, and the crystal grain of each above touches, and the boundary (the so-called twin boundary) where an atomic arrangement serves as a mirror symmetry between two crystal grain is included. The twin boundary is mentioned to the 58th page of the physics (Nikkan Kogyo Shimbun Ltd. (February 28, 1992 issue)) of "metallic material as an example of a "special grain boundary" here, and it is clarified that the twin boundary is generally contained in the grain boundary.
[0014] Drawing 26 cuts the spin bulb film in this invention from a direction parallel to the direction of thickness, it is the photograph which observed the cutting plane with the transmission electron microscope (transverse electromagnetic), and the ** type view is shown in drawing 28 .
[0015] As film composition, a lower shell, Si substrate / 2O3/ground layer of aluminum : Ta (3nm) / seed layer: -- nickel80Fe20/antiferromagnetism layer [:P] t54Mn46 (15nm) / fixed magnetic layer [Co(1.5nm)/Ru(0.8nm)/Co (2.5nm)] / nonmagnetic interlayer: -- Cu (2.5nm) / free magnetic layer: -- [Co (1nm) / nickel80Fe20(3nm)] / BAKKUDO layer: -- a Cu(1.5nm)/Ta/Ta oxide film -- it comes out In addition, the numeric value in parenthesis writing indicated on each class shows thickness. Moreover, the composition ratio of a seed layer, an antiferromagnetism layer, and a free magnetic layer is at%.
[0016] DC magnetron-sputtering equipment performed membrane formation of the aforementioned antiferromagnetism layer and a fixed magnetic layer, and gas pressure of Ar gas used in the case of the aforementioned two-layer membrane formation was set to 3mTorr(s). Moreover, when forming the aforementioned antiferromagnetism layer, distance between a substrate and a target was set to 80mm.
[0017] Heat treatment was performed after forming the spin bulb film which has the above-mentioned film composition. The time of the heat treatment temperature at this time is 2 hours or more above 200 degrees C. In addition, the heat treatment degree of vacuum was set to 10-7Torr. The transmission-electron-microscope photograph shown in drawing 26 shows the state after the above-mentioned heat treatment.
[0018] An interface with the layer which adjoins each class formed above PtMn (antiferromagnetism layer) is not in sight at all, but is in a state like a monolayer so that drawing 26 may show. each constitutes each class by which this was formed above the aforementioned PtMn alloy film from a near element of the atomic number -- having -- **** -- in addition -- since [and] crystal orientation has gathered on each class -- absorption and the diffraction property of an electron ray -- alike -- a passage -- the inside of a transmission-electron-microscope image -- each class -- it is thought that it is because it is hard to produce a difference in contrast
[0019] As shown in drawing 26 on the other hand, the interface with the layer formed above the PtMn alloy film and the aforementioned PtMn alloy film can be grasped clearly.
[0020] And the grain boundary formed in the transmission-electron-microscope photograph at the aforementioned PtMn alloy film and the grain boundary which appears in the layer formed above the PtMn alloy film are also clearly projected on the photograph. The aforementioned grain boundary has many which are formed in the direction of thickness by being prolonged.
[0021] When the ** type view of drawing 28 is referred to here, by the spin bulb film in this invention,

as for the grain boundary (5) formed in the aforementioned PtMn alloy, for example, the grain boundary (1) formed in each class above the aforementioned PtMn alloy film, (2), and (3), it turns out that it is discontinuous by the interface of a PtMn alloy film and the layer on it.

[0022] It is thought that the aforementioned grain boundary (1), (2), (3), and (5) are boundaries where the crystal orientation from which two crystal grain differs is maintained, and the crystal grain of each above touches here. On the other hand, it is thought that the grain boundary (4), (8), (9), (10), and (11) are the twin boundaries from which an atomic arrangement serves as a mirror symmetry within one crystal grain. Each aforementioned twin boundary is parallel and tends to appear.

[0023] It turns out that it is a discontinuous condition by the grain boundary (1) by which the aforementioned grain boundary (4), (8), (9), (10), and (11) were formed in each class above the aforementioned PtMn alloy film, (2), (3), and the interface.

[0024] Thus, about the cause by which the grain boundary formed in the antiferromagnetism layer and the grain boundary formed in the ferromagnetic layer become discontinuous by the interface, although it decided to consider later, the switched connection magnetic field became it very large that it was the spin bulb type thin film from which the transmission-electron-microscope photograph of drawing 26 was acquired, and the switched connection magnetic field of 10.9x104 (A/m) grade was acquired.

[0025] Next, drawing 27 cuts the spin bulb film in the former from a direction parallel to the direction of thickness, it is the photograph which observed the cutting plane with the transmission electron microscope (transverse electromagnetic), and the ** type view is shown in drawing 29 .

[0026] As film composition, a lower shell, Si substrate / 2O3/ground layer of aluminum : Ta (3nm) / seed layer : nickel80Fe20 (2nm) / antiferromagnetism layer :P t44Mn56 (13nm) / fixed magnetic layer [Co(1.5nm)/Ru(0.8nm)/Co (2.5nm)] / nonmagnetic interlayer: -- Cu (2.5nm) / free magnetic layer: -- [Co(1nm)/nickel80Fe20 (3nm)] / BAKKUDO layer: -- a Cu(1.5nm)/Ta/Ta oxide film -- It comes out. In addition, the numeric value in parenthesis writing indicated on each class shows thickness. Moreover, the composition ratio of a seed layer, an antiferromagnetism layer, and a free magnetic layer is at%.

[0027] The amount of Pt(s) of a PtMn alloy film (antiferromagnetism layer) and thickness, and the furthers of the difference from the film composition of the spin bulb film in the above-mentioned this invention are membrane formation conditions etc.

[0028] DC magnetron-sputtering equipment performed membrane formation of the aforementioned antiferromagnetism layer and a fixed magnetic layer, and gas pressure of Ar gas used in the case of the aforementioned two-layer membrane formation was set to 0.8mTorr(s). Moreover, when forming the aforementioned antiferromagnetism layer, distance between a substrate and a target was set to 50mm.

[0029] Heat treatment was performed after forming the spin bulb film which has the above-mentioned film composition. The time of the heat treatment temperature at this time is 2 hours or more above 200 degrees C. In addition, the heat treatment degree of vacuum was set to 10-7Torr. The transmission-electron-microscope photograph shown in drawing 27 shows the state after the above-mentioned heat treatment.

[0030] As drawing 27 shows, it turns out that the lump of the big crystal grain which pierces through each class formed in the direction of thickness on the PtMn alloy film and the aforementioned PtMn alloy film has arisen.

[0031] If the ** type view of drawing 29 is referred to, it pierces through an interface in the layer formed above the PtMn alloy film and the aforementioned PtMn alloy film, and the grain boundary (6) and (7) are formed in it. Namely, in the spin bulb film of the example of comparison, the grain boundary formed in a PtMn alloy film and the grain boundary formed in the layer above the aforementioned PtMn alloy film are in the state where it continued by the aforementioned interface.

[0032] In addition, it is thought that the aforementioned grain boundary (6) and (7) are boundaries where the crystal orientation from which two crystal grain differs is maintained, and the crystal grain of each above touches, and not to form the twin boundary is considered by the aforementioned antiferromagnetism layer.

[0033] In the spin bulb type thin film which has the transmission-electron-microscope photograph shown in drawing 27 , the switched connection magnetic field was very low, and only the switched connection magnetic field of 0.24x104 (A/m) grade was acquired.

[0034] From the former, this invention differs in the position of the grain boundary formed in the aforementioned antiferromagnetism layer in the interface of an antiferromagnetism layer and a ferromagnetic layer, and the grain boundary formed in the ferromagnetic layer as mentioned above.

[0035] In order to make discontinuous the grain boundary formed in the antiferromagnetism layer,

and
the grain boundary formed in the ferromagnetic layer by the interface like this invention, composition of the aforementioned antiferromagnetism layer is important for one, in addition membrane formation conditions are important for it. Ar gas pressure at the time of membrane formation conditions forming heat treatment temperature, heat treatment time and the aforementioned antiferromagnetism layer, and a ferromagnetic layer and a further are the distance between a substrate and a target, substrate temperature, substrate bias voltage, membrane formation speed, etc.

[0036] On the other hand, when the aforementioned antiferromagnetism layer is formed on the different composition and the different membrane formation conditions of an antiferromagnetism layer from this invention, it is a plain-gauze cone to the state where the grain boundary formed in the antiferromagnetism layer and the grain boundary formed in the ferromagnetic layer continued by the interface like the example of comparison seen by drawing 29 .

[0037] By this invention by which the grain boundary in an interface was made discontinuous, in a membrane formation stage, it does not grow up in [an antiferromagnetism layer and a ferromagnetic layer] epitaxial, but it is thought that the atom which constitutes the aforementioned antiferromagnetism layer is not firmly restrained by the crystal structure of a ferromagnetic layer. For this reason, when heat-treating, the aforementioned antiferromagnetism layer metamorphoses into a superlattice appropriately from an irregular grid, and can acquire a big switched connection magnetic field.

[0038] On the other hand, when the grain boundary in an interface is the example of comparison considered as continuation, in a membrane formation stage, it grows up in [an antiferromagnetism layer and a ferromagnetic layer] epitaxial, and it is thought that it will be firmly restrained by the crystal structure of a ferromagnetic layer in the atom of the aforementioned antiferromagnetism layer. For this reason, even if it heat-treats, the aforementioned antiferromagnetism layer will not be able to metamorphose into a superlattice appropriately from an irregular grid, but a switched connection magnetic field will become very small.

[0039] In addition, in this invention, the aforementioned interface sets the grain boundary of the aforementioned antiferromagnetism layer, and the grain boundary of a ferromagnetic layer in part at least, and they should just be in the discontinuous state.

[0040] Moreover, although the different crystal face in the direction parallel to a film surface carries out priority orientation of the crystal orientation of the aforementioned antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is that in which the same desirable equivalent crystal face carries out priority orientation.

[0041] It is desirable that the equivalent crystal face specifically expressed in the direction where the aforementioned antiferromagnetism layer and a ferromagnetic layer are parallel to the aforementioned interface as [111] sides by this invention is carrying out priority orientation. the general term of the equivalent crystal face in the case of the single crystal structure expressed as the aforementioned [111] field using Miller indices -- it is -- the above -- a field, a field (-111), a field (1-11), a field (11-1), a field (-1-11), a field (1-1-1), a field (-11-1), and a field (-1-1-1) exist in the equivalent crystal face (111

[0042] In addition, in the spin bulb type thin film which has the transmission-electron-microscope photograph shown in drawing 26 and drawing 27 , [111] sides and the crystal face with the layer equivalent to the direction where this invention and the example of comparison are parallel to a film surface which the plaid of [111] sides was seen in the direction parallel to both film surfaces, and was formed above the antiferromagnetism layer and the aforementioned antiferromagnetism layer were accepted to carry out priority orientation.

[0043] Thus, when the same equivalent crystal face is carrying out priority orientation in the antiferromagnetism layer and the ferromagnetic layer, it is possible to obtain big resistance rate of change (deltaR/R).

[0044] Moreover, an antiferromagnetism layer and a ferromagnetic layer touch, and are formed, a switched connection magnetic field occurs in the interface of the aforementioned antiferromagnetism layer and a ferromagnetic layer, and this invention is set on the switched connection film with which the magnetization direction of the aforementioned ferromagnetic layer is carried out in the fixed direction. The equivalent crystal face expressed in the direction parallel to the aforementioned interface as [111] sides carries out priority orientation of the aforementioned antiferromagnetism layer, twin crystal is formed in the aforementioned antiferromagnetism layer in part at least, and the twin boundary of a part of [at least] aforementioned twin crystal is characterized by being formed in aforementioned being the interface and being un-parallel.

[0045] In this invention, the equivalent crystal face expressed in the direction parallel to the

aforementioned interface as [111] sides is carrying out priority orientation of the antiferromagnetism layer. In addition, it is effective to cover with a seed layer for carrying out [111] plane orientation of the aforementioned antiferromagnetism layer at the aforementioned antiferromagnetism layer bottom.

[0046] Although the twin boundary of a part of [at least] twin crystal formed in the antiferromagnetism layer is formed in aforementioned being the interface and being un-parallel in this invention, it is clear if drawing 26 and drawing 28 are seen.

[0047] That is, as shown in drawing 26 and drawing 28 , twin crystal was formed in the antiferromagnetism layer and the grain boundary (4) which shows the twin boundary, (8), (9), (10), and (11) have appeared in the aforementioned twin crystal in it. And each of these twin boundaries is an interface and un-parallel.

[0048] Moreover, the film composition shown in drawing 26 cuts the thing of different film composition from a direction parallel to thickness, and shows the photograph which observed the cutting plane with the transmission electron microscope (transverse electromagnetic) to drawing 30 here.

[0049] Film composition A lower shell, Si substrate / 2O3/ground layer of aluminum : Ta (3nm) / seed layer : nickel80Fe20 (2nm) / antiferromagnetism layer :P t49Mn51 (16nm) / fixed magnetic layer [Co90Fe10 (1.4nm) / Ru (0.9nm) / Co90Fe10(2.2nm)] / nonmagnetic interlayer: -- Cu (2.2nm) / free magnetic layer: -- they are [Co90Fe10(1nm)/nickel80Fe20 (4nm)] / Ta (3nm) In addition, the numeric value in a parenthesis shows thickness. In addition, the composition ratio of an antiferromagnetism layer, a fixed magnetic layer, and a free magnetic layer is at%.

[0050] DC magnetron-sputtering equipment performed membrane formation of the aforementioned antiferromagnetism layer and a fixed magnetic layer, and gas pressure of Ar gas used in the case of the aforementioned two-layer membrane formation was set to 2.5mTorr(s). Moreover, when forming the aforementioned antiferromagnetism layer, distance between a substrate and a target was set to 80mm.

[0051] Heat treatment was performed after forming the spin bulb film which has the above-mentioned film composition. The time of the heat treatment temperature at this time was 4 hours at 270 degrees C. Moreover, the heat treatment degree of vacuum was set to 10-7Torr. In addition, in this example, the composition ratio of the thing of drawing 26 and PtMn differs from thickness, membrane formation conditions, etc.

[0052] The transmission-electron-microscope photograph shown in drawing 30 shows the state after the above-mentioned heat treatment. Moreover, the antiferromagnetism layer and the ferromagnetic layer were understood that [111] sides equivalent to a direction parallel to an interface are carrying out priority orientation with the electron-diffraction image.

[0053] Drawing 31 is the ** type view of the transverse-electromagnetic photograph shown in drawing 30 . As shown in drawing 31 , it turns out that two or more twin boundaries are formed in an antiferromagnetism layer, and no these twin boundaries are parallel to it with an interface with a ferromagnetic layer.

[0054] In the example of comparison it is indicated to drawing 27 and drawing 29 that already explained on the other hand, twin crystal is not formed in an antiferromagnetism layer, but, therefore, it turns out that the twin boundary has not appeared.

[0055] When twin crystal is formed in an antiferromagnetism layer and the twin boundary is formed in the aforementioned twin crystal like this invention aforementioned being the interface and being un-parallel, with heat treatment, the aforementioned antiferromagnetism layer is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire a big switched connection magnetic field. The switched connection magnetic field in the film composition shown in drawing 30 was about 9.3x104 (A/m).

[0056] By the way, it is not important whether the aforementioned twin boundary is formed in the membrane formation stage. The aforementioned twin boundary like this invention may appear by heat-treating, even if the aforementioned twin boundary is not formed in a membrane formation stage.

[0057] In this invention, it is thought that it will be restrained by the crystal structure of a ferromagnetic layer in a membrane formation stage in the atom of the aforementioned antiferromagnetism layer. Thus, since a lattice strain will occur in the case of the aforementioned transformation although the aforementioned antiferromagnetism layer becomes easy to metamorphose into a superlattice with heat treatment from an irregular grid, if the restraint in an interface becomes weak, unless it can ease this lattice strain appropriately, the aforementioned transformation cannot be caused effectively. When metamorphosing, the atom of an antiferromagnetism layer starts the rearrangement from an irregular grid to a superlattice, and it is

thought that the lattice strain produced at this time is eased because an atomic arrangement changes to a mirror symmetry at intervals of a short distance. The boundary of the aforementioned mirror-symmetry change serves as the twin boundary after heat treatment, and that such the twin boundary is formed means that the rule-ized transformation has taken place, when heat-treating so to speak.

[0058] Near the interface of an antiferromagnetism layer and a ferromagnetic layer, in order to ease the lattice strain produced when an atom carries out a rearrangement in the direction parallel to the aforementioned interface, the aforementioned twin boundary is formed in the direction at which the aforementioned interface is crossed here. For this reason, when a rule-ized transformation suitable on the whole occurs, the aforementioned twin boundary is formed in aforementioned being the interface and being un-parallel. This is this invention, and when the twin boundary is formed in being an interface and being un-parallel like this invention, it becomes possible to acquire a very big switched connection magnetic field. When the rearrangement of the atom cannot be carried out in the direction parallel to the aforementioned interface on the other hand (i.e., when the atom of the aforementioned antiferromagnetism layer is firmly restrained by the crystal structure of a ferromagnetic layer in the interface etc.), the twin boundary is not formed so that the aforementioned interface may be crossed. In this case, the aforementioned twin boundary is not formed or the twin boundary parallel to the aforementioned interface is formed.

[0059] In addition, two or more aforementioned twin boundaries become almost parallel [each twin boundaries], when formed in the same twin crystal like drawing 26 or drawing 30 .

[0060] In addition, as for the grain boundary by which the aforementioned grain boundary and the twin
boundary which the grain boundary which has special symmetric relation in neither of the antiferromagnetism layer and the ferromagnetic layer of an example which are shown in drawing 30 is formed, and were formed in the antiferromagnetism layer side were formed in the ferromagnetic layer, it turns out that it is in a discontinuous state in an interface.

[0061] Moreover, as for the interior angle between the aforementioned twin boundary and the aforementioned interface, in this invention, it is desirable that it is 76 degrees or less at 68 degrees or more. [111] sides equivalent to a direction parallel to an interface carry out priority orientation of the aforementioned antiferromagnetism layer to it being this within the limits.

[0062] Moreover, as for the aforementioned ferromagnetic layer, in this invention, it is desirable that the equivalent crystal face expressed in the direction parallel to the aforementioned interface as [111] sides is carrying out priority orientation.

[0063] If the equivalent crystal face with which the aforementioned antiferromagnetism layer and a ferromagnetic layer are expressed in the direction parallel to both interfaces as [111] sides like this invention is carrying out priority orientation, it is possible to obtain big resistance rate of change.

[0064] Moreover, as for the aforementioned antiferromagnetism layer, in this invention, it is desirable to be formed with the antiferromagnetism material containing Elements X (however, for X to be one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os) and Mn.

[0065] Moreover, in this invention, the seed layer was formed in the aforementioned antiferromagnetism layer bottom so that the crystal orientation in a direction parallel to the film surface of an antiferromagnetism layer and a ferromagnetic layer as mentioned above might serve as the equivalent crystal face expressed as [111] sides.

[0066] It is desirable that the laminating of the aforementioned switched connection film is carried out to the order of a lower shell antiferromagnetism layer and a ferromagnetic layer at this invention, the crystal structure changes mainly from a face-centered cubic to the aforementioned antiferromagnetism layer bottom further, and the seed layer the equivalent crystal face expressed as [111] sides carried out [the layer] priority orientation is moreover formed in the direction parallel to the aforementioned interface.

[0067] Thus, by this invention, the equivalent crystal face typically expressed in the direction parallel to a film surface as [111] sides carries out priority orientation of the aforementioned antiferromagnetism layer and the ferromagnetic layer by preparing a seed layer in the antiferromagnetism layer bottom.

[0068] Moreover, in this invention, it is desirable a NiFe alloy, nickel or nickel-Fe-Y alloy (however, at least one or more sorts as which Y is chosen from Cr, Rh, Ta, Hf, Nb, Zr, and Ti), and that the aforementioned seed layer is further formed with nickel-Y alloy.

[0069] Moreover, an empirical formula is shown by 1(nickel1-xFex)-yYy (x and y are a rate of an atomic ratio), it is 0.3 or less or more in zero, and, as for the rate x of an atomic ratio, it is desirable as for the aforementioned seed layer / the rate y of an atomic ratio] that it is 0.5 or less or more in zero. Moreover, as for the aforementioned seed layer, it is desirable that it is nonmagnetic in ordinary

temperature.
[0070] Moreover, it is desirable that the ground layer formed by at least one or more sorts of elements among Ta, Hf, Nb, Zr, Ti, Mo, and W is formed in the bottom of the aforementioned seed layer in this invention.
[0071] As for a part of interface [at least] of the aforementioned antiferromagnetism layer and a seed layer, in this invention, it is still more desirable that it is in a disconformity state. A disconformity state points out the thing in the state where the atom which constitutes an antiferromagnetism layer, and the atom which constitutes a ferromagnetic layer (seed layer, in addition a room temperature nonmagnetic) do not correspond to 1 to 1 by the interface here. On the other hand, an adjustment state points out the thing in the state where an atom corresponds by the aforementioned interface 1 to 1.
[0072] By the way, although the grain boundary formed in the antiferromagnetism layer and the grain boundary formed in the ferromagnetic layer are in the discontinuous state by a part of interface [at least] by this invention as described above, as for this crystal structure, it is desirable to be generated also in the interface of the aforementioned antiferromagnetism layer and a seed layer.
[0073] That is, it is desirable that the grain boundary formed in the antiferromagnetism layer and the grain boundary formed in the seed layer are in a discontinuous state according to a part of interface at least] in this invention. The aforementioned antiferromagnetism layer has caused the suitable rule transformation by this, without being restrained by the crystal structure of the aforementioned seed layer when heat-treating, and it becomes possible to acquire a big switched connection magnetic field.
[0074] Moreover, at this invention, the aforementioned antiferromagnetism layer is a X-Mn-X' alloy (however, element X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements -- one sort or two sorts or more of elements -- it is -- it may be formed In this case, as for the aforementioned X-Mn-X' alloy, it is desirable that it is the interstitial solid solution by which element X' trespassed upon the crevice between the space lattices which consist of elements X and Mn, or a part of lattice point of the crystal lattice which consists of elements X and Mn is the substitution solid solution replaced by element X'. It is possible to form the atomic arrangement which can extend the lattice constant of an antiferromagnetism layer and does not correspond to 1 to 1 to the atomic arrangement of the aforementioned ferromagnetic layer in an interface with a ferromagnetic layer by this.
[0075] Moreover, as for the aforementioned element X or the composition ratio of element X+X', in this invention, it is desirable that it is below 60 (at%) more than 45 (at%). By the experimental result mentioned later, the switched connection magnetic field more than 1.58x104 (A/m) can be acquired at least as the aforementioned element X or the composition ratio of element X+X' is above-mentioned] within the limits. In addition, the aforementioned element X or the composition ratio of element X+X' is below 56.5 (at%) more than 49 (at%) more preferably.
[0076] Moreover, as for a part of interface [at least] of the aforementioned antiferromagnetism layer and a ferromagnetic layer, in this invention, it is desirable that it is in a disconformity state.
[0077] In this invention, the above-mentioned switched connection film is applicable to various magnetoresistance-effect elements.
[0078] The fixed magnetic layer to which this invention is formed in in contact with an antiferromagnetism layer and this antiferromagnetism layer, and the magnetization direction is fixed by the exchange-anisotropy magnetic field with the aforementioned antiferromagnetism layer, The free magnetic layer formed in the aforementioned fixed magnetic layer through the nonmagnetic interlayer, It has the bias layer which arranges the magnetization direction of the aforementioned free magnetic layer in the magnetization direction of the aforementioned fixed magnetic layer, and the crossing direction, and the fixed magnetic layer formed in contact with the aforementioned antiferromagnetism layer and this antiferromagnetism layer is characterized by being formed with the above-mentioned switched connection film.
[0079] Moreover, the fixed magnetic layer to which this invention is formed in in contact with an antiferromagnetism layer and this antiferromagnetism layer, and the magnetization direction is fixed by the exchange-anisotropy magnetic field with the aforementioned antiferromagnetism layer, It has the free magnetic layer formed in the aforementioned fixed magnetic layer through the nonmagnetic interlayer. Vacate the interval of the width of recording track Tw for the aforementioned free magnetic layer top or bottom, and the exchange bias layer of antiferromagnetism is formed in it. The aforementioned exchange bias layer and a free magnetic layer are formed with the above-mentioned switched connection film, and it is characterized by carrying out magnetization of the aforementioned free magnetic layer in the fixed direction.

[0080] Moreover, the nonmagnetic interlayer by whom the laminating of this invention was done to the upper and lower sides of a free magnetic layer and the fixed magnetic layer located on one aforementioned nonmagnetic interlayer and under the nonmagnetic interlayer of another side, It is located on one aforementioned fixed magnetic layer and under the fixed magnetic layer of another side. The antiferromagnetism layer which fixes the magnetization direction of each fixed magnetic layer in the fixed direction by the exchange-anisotropy magnetic field, It has the bias layer which arranges the magnetization direction of the aforementioned free magnetic layer in the magnetization direction of the aforementioned fixed magnetic layer, and the crossing direction, and the fixed magnetic layer formed in contact with the aforementioned antiferromagnetism layer and this antiferromagnetism layer is characterized by being formed with the above-mentioned switched connection film.
[0081] Moreover, this invention is characterized by having the magnetic-reluctance layer and soft-magnetism layer which were piled up through the non-magnetic layer, vacating the interval of the width of recording track Tw for the aforementioned magnetic-reluctance layer top or bottom, forming an antiferromagnetism layer, and forming the aforementioned antiferromagnetism layer and the magnetic-reluctance layer with the above-mentioned switched connection film.
[0082] Moreover, the thin film magnetic head in this invention is characterized by forming the shield layer in the upper and lower sides of the above-mentioned magnetoresistance-effect element through a gap layer.
[0083]
[Embodiments of the Invention] Drawing 1 is the cross section which looked at the whole single spin bulb type magnetoresistance-effect element structure of the 1st operation gestalt of this invention from the ABS side side. In addition, drawing 1 fractures and shows only a part for the center section of the element prolonged in the direction of X.
[0084] This single spin bulb type magnetoresistance-effect element is prepared in the trailing side edge section of the surfacing formula slider formed in the hard disk drive unit etc., and detects record magnetic fields, such as a hard disk. In addition, the move direction of magnetic-recording media, such as a hard disk, is a Z direction, and the direction of the leak magnetic field from a magnetic-recording medium is the direction of Y.
[0085] The ground layer 6 formed among Ta, Hf, Nb, Zr, Ti, Mo, and W with non-magnetic materials, such as one sort or two sorts or more of elements, is formed in the bottom of drawing 1 . The aforementioned ground layer 6 is formed in order to make the priority orientation of the equivalent crystal face expressed as {111} sides of the seed layer 22 formed on it carry out in the direction parallel to a film surface. The aforementioned ground layer 6 is formed by about 50A thickness.
[0086] The aforementioned seed layer 22 consists mainly of a face-centered cubic, and priority orientation of the equivalent crystal face typically expressed in the direction parallel to an interface with the aforementioned antiferromagnetism layer 4 as {111} sides is carried out. As for the aforementioned seed layer 22, it is desirable to be formed with a NiFe alloy, nickel or nickel-Fe-Y alloy (however, at least one sort or two sorts or more as which Y is chosen from Cr, Rh, Ta, Hf, Nb, Zr, and Ti), and nickel-Y alloy.
[0087] In addition, an empirical formula is shown by 1(nickel1-xFex)-yYy (x and y are a rate of an atomic ratio), the rate x of an atomic ratio is 0.3 or less or more in zero, and, as for the rate y of an atomic ratio, it is desirable [the aforementioned seed layer 22] that it is 0.5 or less or more in zero. By this, the priority amount of preferred orientation of the [111] sides of the antiferromagnetism layer 4 and each class on it can be raised, and resistance rate-of-change deltaR/R can be raised.
[0088] "The equivalent crystal face" shows the crystal plane expressed using Miller indices here. As the equivalent (equivalent) crystal face expressed as the aforementioned [111] field, a field (111), a field (-111), a field (1-11), a field (11-1), a field (-1-11), a field (1-1-1), a field (-11-1), and a field (-1-1-1) exist.
[0089] Namely, in this invention, the field (111), the field equivalent (1-11) to it, etc. are carrying out priority orientation of the aforementioned seed layer 22 in the direction parallel to a film surface.
[0090] Moreover, as for the aforementioned seed layer 22, in this invention, it is desirable that it is nonmagnetic in ordinary temperature. while being able to prevent wave-like asymmetric (asymmetry) aggravation by making the aforementioned seed layer 22 nonmagnetic in ordinary temperature, it is possible to suppress diverging of the sense current which can enlarge specific resistance of the aforementioned seed layer 22, and flows from a conductive layer according to the effect of the element Y (after-mentioned) added in order to make it nonmagnetic through which it passes aforementioned] seed layer 22 It leads to decline in resistance rate of change (deltaR/R), or generating of a Barkhausen noise and is not desirable if it becomes easy to shunt the aforementioned sense current toward the seed layer 22.

[0091] In order to form the aforementioned seed layer 22 by nonmagnetic, nickel-Fe-Y alloy (however, at least one sort or two sorts or more as which Y is chosen from Cr, Rh, Ta, Hf, Nb, Zr, and Ti), and nickel-Y alloy can be chosen among the above-mentioned quality of the materials. The crystal structure is a face-centered cubic, and these quality of the materials are easy to carry out priority orientation and have the equivalent desirable crystal face moreover typically expressed in the direction parallel to a film surface as a {111} side. The aforementioned seed layer 22 is formed by about 30A.
[0092] The antiferromagnetism layer 4 is formed on the aforementioned seed layer 22. As for the aforementioned antiferromagnetism layer 4, it is desirable to be formed with the antiferromagnetism material containing Elements X (however, for X to be one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os) and Mn.
[0093] The X-Mn alloy using these platinum group metals has the property which was excellent in corrosion resistance and was excellent as an antiferromagnetism material -- blocking temperature is also high and a switched connection magnetic field (Hex) can be enlarged further. It is desirable to use Pt especially among platinum group metals. for example, duality -- the PtMn alloy formed by the system can be used
[0094] Moreover, at this invention, it is the aforementioned antiferromagnetism layer 4 Element X and element X' (however, element X') Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Sn, Hf, Ta, W, Re, Au, Pb, And you may form with the antiferromagnetism material which contains Mn as they are one sort or two sorts or more of elements among rare earth elements.
[0095] In addition, it is desirable to use for aforementioned element X' the element replaced by a part of lattice point of the crystal lattice which trespasses upon the crevice between the space lattices which consist of elements X and Mn, or consists of elements X and Mn. The solid solution has pointed out the thing of the solid-state with which the component was uniformly mixed in one crystal phase here.
[0096] Interface structure of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 can be made easy to be able to extend a difference with the lattice constant of the fixed magnetic layer 3 mentioned later, and to change into a disconformity state, since the lattice constant of the aforementioned X-Mn-X' alloy can be enlarged by considering as an interstitial solid solution or a substitution solid solution compared with the lattice constant of the aforementioned X-Mn alloy film. Moreover, if the composition ratio of aforementioned element X' becomes large too much when using element X' which dissolves especially with a replaced type, the property as antiferromagnetism will fall and the switched connection magnetic field generated in an interface with the fixed magnetic layer 3 will become small. By this invention, it especially dissolves with an invaded type, and it is supposed that it is desirable to use the rare-gas element (one sort or two sorts or more among Ne, Ar, Kr, and Xe) of inert gas as element X'. It is gas by which it is not greatly affected in an antiferromagnetism property even if a rare-gas element contains in a film, since a rare-gas element is inert gas, and Ar etc. is further introduced in the sputtering system from the former as spatter gas, and is only adjusting gas pressure proper, and Ar can be made to invade into a film easily.
[0097] In addition, although it is difficult to contain a lot of element X' in a film when the element of a gas system is used for element X', in the case of rare gas, a minute amount invasion is only carried out into a film, and the switched connection magnetic field generated with heat treatment can be enlarged by leaps and bounds.
[0098] In addition, in this invention, the desirable composition range of aforementioned element X' is 0.2 to 10 at at%, is at% more preferably, and is 0.5 to 5. Moreover, in this invention, as for the aforementioned element X, it is desirable that it is Pt, and it is desirable to use a Pt-Mn-X' alloy therefore.
[0099] Next, on the aforementioned antiferromagnetism layer 4, the fixed magnetic layer 3 formed by three layer membranes is formed.
[0100] The aforementioned fixed magnetic layer 3 is formed by the Co film 11, the Ru film 12, and the Co film 13, and RKKY-antiferromagnetism combination which works through the Ru film 12 between the switched connection magnetic field in an interface with the aforementioned antiferromagnetism layer 4 and the aforementioned Co film 11, and the Co film 13 changes mutually the magnetization direction of the aforementioned Co film 11 and the Co film 13 into an anti-parallel state. This can enlarge the switched connection magnetic field which is called so-called ferrimagnetism integrated state, and changes into the state where magnetization of the fixed magnetic layer 3 was stabilized by this composition, and is generated in the interface of the aforementioned fixed magnetic layer 3 and the antiferromagnetism layer 4.
[0101] In addition, the aforementioned Co film 11 is formed by about 20A, the Ru film 12 is formed by

about 8A, and the Co film 13 is formed by about 15A.
[0102] In addition, the aforementioned fixed magnetic layer 3 does not need to be formed by three layer membranes, for example, may be formed by the monolayer. Moreover, you may form each class 11, 12, and 13 by material other than the above-mentioned magnetic material. For example, CoFe etc. can be chosen as the aforementioned layer 11 or 13 other than Co.
[0103] The nonmagnetic interlayer 2 is formed on the aforementioned fixed magnetic layer 3. The aforementioned nonmagnetic interlayer 2 is formed by Cu. In addition, in the case of the magnetoresistance-effect element's in this invention tunnel type magnetoresistance-effect element (TMR element) using the principle of the tunnel effect, the aforementioned nonmagnetic interlayer 2 is formed by the insulating material of for example, aluminum2O3 grade.
[0104] Furthermore on the aforementioned nonmagnetic interlayer 2, the free magnetic layer 1 formed by the two-layer film is formed.
[0105] The aforementioned free magnetic layer 1 is formed by two-layer [of the NiFe alloy film 9 and the Co film 10]. By forming the aforementioned Co film 10 in the side which touches the nonmagnetic interlayer 2, as shown in drawing 1 , diffusion of the metallic element in an interface with the aforementioned nonmagnetic interlayer 2 etc. can be prevented, and deltaR/R (resistance rate of change) can be enlarged.
[0106] In addition, the aforementioned NiFe alloy film 9 forms 80 (at%) and Fe for example, for the above nickel as 20 (at%). Moreover, the thickness of the aforementioned NiFe alloy film 9 is formed by about 45A, and Co film is formed by about 5A.
[0107] As shown in drawing 1 , on the aforementioned free magnetic layer 1, the protective layer 7 formed among Ta, Hf, Nb, Zr, Ti, Mo, and W with non-magnetic materials, such as one sort or two sorts or more of elements, is formed.
[0108] Furthermore, the hard bias layer 5 and the conductive layer 8 are formed in the both sides of the cascade screen from the aforementioned ground layer 6 to a protective layer 7. Magnetization of the free magnetic layer 1 is arranged in the direction of the width of recording track (the direction of illustration X) by the bias magnetic field from the aforementioned hard bias layer 5.
[0109] The aforementioned hard bias layers 5 and 5 are formed with for example, the Co-Pt (cobalt-platinum) alloy, the Co-Cr-Pt (cobalt-chromium-platinum) alloy, etc., and conductive layers 8 and 8 are formed by alpha-Ta, Au, Cr and Cu (copper), W (tungsten), etc. In addition, in the case of the above-mentioned tunneled type magnetoresistance-effect element, the aforementioned conductive layers 8 and 8 will be formed in the free magnetic layer 1 bottom and the antiferromagnetism layer 4 bottom, respectively.
[0110] Moreover, in this invention, the BAKKUDO layer which consists of Cu, Au, and Ag of a metallic material or non-magnetic metal may be formed on the above-mentioned free magnetic layer 1. For example, the thickness of the aforementioned BAKKUDO layer is formed by about 12-20A.
[0111] Moreover, it is desirable that the oxidizing zone to which it changed from Ta etc. and the front face oxidized is formed in the aforementioned protective layer 7.
[0112] By forming the aforementioned BAKKUDO layer, the average free process (mean free path) in the electron of + spin (upward spin : up spin) which contributes to the magnetoresistance effect is extended, big resistance rate of change is obtained in a spin bulb type magnetic cell according to the so-called spin-filter effect (spin filter effect), and it can respond to high recording density-ization.
[0113] Although heat-treat, the interface of the antiferromagnetism layer 4 and the fixed magnetic layer 3 is made to generate a switched connection magnetic field (Hex) and this fixes magnetization of the aforementioned fixed magnetic layer 3 in the height direction (the direction of illustration Y) in this invention after carrying out the laminating of above-mentioned each class, it has the following crystal orientation in the aforementioned spin bulb type thin film after heat treatment.
[0114] About the aforementioned crystal orientation, the center of the switched connection film mainly formed in an antiferromagnetism layer and a ferromagnetic layer (fixed magnetic layer) is carried out, and it is explained.
[0115] In this invention, as described above, the seed layer 22 is formed in the antiferromagnetism layer 4 bottom. Priority orientation of the crystal face same in a direction parallel to a film surface as the aforementioned seed layer 22 is carried out also for the antiferromagnetism layer 4 formed on the aforementioned seed layer 22 of this although it is formed so that the equivalent crystal face to which the aforementioned seed layer 22 is typically expressed as [111] sides may carry out priority orientation to a film surface to a film surface and a parallel direction.
[0116] For example, when a field (-111) carries out priority orientation of the seed layer 22 in the direction parallel to a film surface, also in the antiferromagnetism layer 4 formed on the aforementioned seed layer 22, a field (-111) carries out priority orientation of it in the direction parallel to a film surface.

[0117] The same equivalent crystal face as the aforementioned antiferromagnetism layer 4 carries out priority orientation also of the fixed magnetic layer 3 furthermore formed on the aforementioned antiferromagnetism layer 4 in the direction parallel to a film surface.
[0118] That is, in this invention, the same equivalent crystal face typically expressed in the direction parallel to a film surface as {111} sides is carrying out priority orientation of the seed layer 22, the antiferromagnetism layer 4, and the fixed magnetic layer 3.
[0119] In addition, although it is desirable that it is the equivalent crystal face typically expressed as [111] sides as for the crystal face which carries out priority orientation in the direction parallel to the aforementioned film surface in this invention, this is because the aforementioned crystal face is the maximum ****. For example, if the environmental temperature and sense current density in magnetic-head equipment become high, although thermal stability will be searched for especially, the thermal stability of a multilayer interface is able for diffusion of the atom of the direction of thickness to be unable to take place easily, if the equivalent crystal face expressed in the direction parallel to a film surface as [111] sides which are the maximum **** carries out priority orientation, and to attain stabilization of increase and a property.
[0120] By this invention, in this way, although the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, they have turned to a direction different mutually [a part of a certain same crystallographic axis / at least / which exists in the aforementioned crystal face] at the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 by this invention further (refer to drawing 14). In addition, in drawing 14 , it turns out that the direction where the [110] directions which exist, for example (111) in a field differ mutually by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 is turned to.
[0121] It is thought that it depends for the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 on in what state membranes were formed in a membrane formation stage (before heat treatment) as a cause which produces such crystal orientation.
[0122] For example, the quality of the material and the composition ratio of the antiferromagnetism layer 4 are adjusted, and if each class is formed where it controlled membrane formation conditions etc. further and the lattice constant of the aforementioned antiferromagnetism layer 4 is made larger enough than the lattice constant of the fixed magnetic layer 3, it will be thought that the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 seldom carry out epitaxial growth.
[0123] If membranes are formed in epitaxial, all crystal orientation will have an parallel relation and will
be easy to be formed by the antiferromagnetism layer 4 and the fixed magnetic layer 3. And the same equivalent crystal face as a direction parallel to the aforementioned interface not only carries out priority orientation, but according to the interface of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3, the array of the atom of the antiferromagnetism layer 4 and the array of the atom of the fixed magnetic layer 3 become easy to respond to 1 to 1 by the aforementioned interface toward the direction where the existing same equivalent crystallographic axis of the antiferromagnetism layer 4 and the fixed magnetic layer 3 which exist in the aforementioned crystal face is the same (refer to drawing 15) In addition, having turned to the direction where the [110] directions which exist in a field (111) are the same in the antiferromagnetism layer 31 and the ferromagnetic layer 30 as a concrete example is shown in drawing 15 .
[0124] If generated in the stage before such crystal orientation heat-treating, even if the aforementioned antiferromagnetism layer 4 heat-treats, it will be restrained by the crystal structure of the fixed magnetic layer 3, and a suitable rule transformation will not be able to be caused, but a switched connection magnetic field will fall very much.
[0125] In this invention, if it is thought that the antiferromagnetism layer 4 and the fixed magnetic layer 3 were formed without carrying out the above epitaxial growth and it heat-treats in the state of such membrane formation, the aforementioned antiferromagnetism layer 4 will not be restrained by the crystal structure of the fixed magnetic layer 3, but will cause a suitable rule transformation.
When the membrane structure of the spin bulb film in this invention after heat treatment is observed, the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 Though the same equivalent crystal face carries out priority orientation in the direction parallel to a film surface mutually, in other crystal faces which do not carry out orientation in the direction parallel to the aforementioned film surface A part of a certain same equivalent crystallographic axis [at least] has turned to a direction which exists in the aforementioned crystal face which did not maintain an parallel relation by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3, consequently carried out orientation to aforementioned film surface parallel and which is mutually

different by the antiferromagnetism layer 4 and the fixed magnetic layer 3.

[0126] In this invention, the antiferromagnetism layer 4 bottom was covered with the seed layer 22 as one method for producing the above-mentioned crystal orientation. As already explained, the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3 which are formed on the aforementioned seed layer 22 by forming the seed layer 22, and such crystal orientation brings about big resistance rate of change (deltaR/R).

[0127] moreover -- this invention -- the film surface of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3, although a part of a certain same equivalent crystallographic axis [at least] has turned to a mutually different direction which exists in the aforementioned crystal face which carries out orientation in the parallel direction The ** from which the aforementioned antiferromagnetism layer 4 is not restrained for such existence of crystal orientation by the crystal structure of the fixed magnetic layer 3 in a heat treatment stage, It is possible it to be thought for that it metamorphosed from the face-centered cubic lattice as an irregular phase suitable for a face centred tetragonal lattice CuAu-I type [as a rule phase], and to acquire a big switched connection magnetic field compared with the former. In addition, in this invention, a part of at least] crystal structures of the aforementioned antiferromagnetism layer 4 should just serve as an CuAu-I type face-centered square superlattice after heat treatment.

[0128] Moreover, it is important when acquiring a switched connection magnetic field with big having the following crystalline structures in this invention.

[0129] Namely, by this invention, the grain boundary of the aforementioned antiferromagnetism layer 4 which appears in the aforementioned cutting plane, and the grain boundary of the fixed magnetic layer 3 are in the discontinuous state by a part of interface [at least] of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.

[0130] In addition, the aforementioned grain boundary said by this invention is a boundary where the crystal orientation from which two crystal grain differs is maintained, and the crystal grain of each above touches, and the boundary (the so-called twin boundary) where an atomic arrangement serves as a mirror symmetry between two crystal grain is included. The grain boundary (1) shown in drawing 28 , (2), (3), and (5) are the former boundaries without special symmetric relation, and they are considered for the grain boundary (4) shown in drawing 28 , (8), (9), (10), and (11) to be the latter twin boundaries.

[0131] To drawing 26 and 28 (** type view of the photograph which shows drawing 26 to a transmission-electron-microscope photograph (transverse-electromagnetic photograph), and shows drawing 28 to drawing 26) so that it may be shown in this invention The grain boundary (4), (5), (8), (9), (10), and (11) which were formed in the PtMn alloy film (antiferromagnetism layer 4), When the grain boundary (1) formed in the antiferromagnetism layer 4 aforementioned upper layer, (2), and (3) are in the discontinuous state by the aforementioned interface and such a discontinuous condition arises The thing which exists in the crystal face of the direction of a film surface of the antiferromagnetism layer 4 and the crystal face of the direction of a film surface of the fixed magnetic layer 3 in the aforementioned interface and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ can be conjectured. Moreover, also in drawing 30 mentioned as another example, and 31, it turns out that the grain boundary without special symmetric relation formed in the antiferromagnetism layer and the twin boundary are discontinuous by the grain boundary and interface which were formed in the ferromagnetic layer.

[0132] It turns out that it differs from the crystalline structure shown in drawing 27 to which drawing 26 and the crystal structure shown in 28, 30, and 31 are expressed as an example of comparison, and 29 (** type view of the photograph which shows drawing 27 to a transmission-electron-microscope photograph (transverse-electromagnetic photograph), and shows drawing 29 to drawing 27) clearly. In drawing 27 and 29, it is because the big crystal grain to which the grain boundary formed in the PtMn alloy film (antiferromagnetism layer 4) and the grain boundary formed in the layer on a PtMn alloy film are missing from the layer on it from the antiferromagnetism layer 4 continuously by the interface, and pierces through the aforementioned interface is formed.

[0133] It is thought that membranes were formed without carrying out epitaxial growth of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 to their being drawing 26 and the switched connection film which has the grain boundary as shown in 28, 30, and 31 in a membrane formation stage like this invention, therefore with heat treatment, the aforementioned antiferromagnetism layer 4 has caused the suitable rule transformation, without being restrained by the crystal structure of the fixed magnetic layer 3, and can acquire the big switched connection

magnetic field.
[0134] Moreover, it turns out that the grain boundary (4) shown in drawing 28 , (8), (9), (10), and (11), i.e., the twin boundary, are not parallel to an interface. It turns out that the twin boundary similarly shown in drawing 30 and drawing 31 as another example is not parallel to the aforementioned interface, either. In addition, in any example in this invention, since the aforementioned antiferromagnetism layer bottom is covered with the seed layer layer, the equivalent crystal face expressed in the direction parallel to the aforementioned interface as [111] sides is carrying out priority orientation of the aforementioned antiferromagnetism layer.
[0135] In addition, twin crystal means one solid-state which two or more single crystals of one matter have combined according to specific symmetric relation. And the twin boundary is formed in the aforementioned twin crystal, and the atomic arrangement serves as a mirror symmetry bordering on the aforementioned twin boundary. Such twin crystal arises because [of relief of internal stress]. Even if the twin boundary is incidentally formed and relief of internal stress is promoted, when big internal stress has occurred in a certain portion, already, by the twin boundary, the boundary where suitable internal stress cannot be eased, the crystal orientation from which two crystal grain like the grain boundary (5) of drawing 28 and the grain boundary of drawing 30 differs is maintained, and the crystal grain of each above touches is formed, and it is thought that the aforementioned big internal stress is eased.
[0136] When the twin boundary formed in the aforementioned antiferromagnetism layer like this invention is not parallel to an interface, the thing which exists in the crystal face of the direction of a film surface of the antiferromagnetism layer 4 and the crystal face of the direction of a film surface of the fixed magnetic layer 3 in the aforementioned interface and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ can be conjectured.
[0137] Although it cannot acquire a big switched connection magnetic field if **** does not have the transformation to a superlattice from an irregular grid by performing heat treatment after membrane formation as for the aforementioned antiferromagnetism layer 4, the twin boundary from which an atomic arrangement changes to a mirror symmetry is formed that the lattice strain produced when an atom moves in a direction parallel to an interface and the direction of thickness should be eased at the time of a transformation. And the aforementioned twin boundary is formed in aforementioned being the interface and being un-parallel at this time.
[0138] If the aforementioned antiferromagnetism layer metamorphoses suitable for a superlattice from an irregular grid, the twin boundary which is the aforementioned interface and un-parallel will be
formed in the aforementioned antiferromagnetism layer, and a big switched connection magnetic field will occur. In addition, in a certain twin crystal, two or more aforementioned twin boundaries may be formed, and, in this case, each aforementioned twin boundaries will be in an parallel state mostly.
[0139] On the other hand, in drawing 27 and drawing 29 which show the example of comparison, the twin boundary is not formed in the aforementioned antiferromagnetism layer at all. Even if it gives this, i.e., heat treatment, it is because the rearrangement which happens at the time of a transformation has not accomplished the atom of the aforementioned antiferromagnetism layer, and therefore, the transformation to a superlattice from an irregular grid hardly advances, but can acquire only a small switched connection magnetic field.
[0140] Moreover, although it can surmise that the lattice strain to the direction of thickness is eased to some extent when the aforementioned twin boundary is parallel to the aforementioned interface even if the twin boundary is formed in the aforementioned antiferromagnetism layer, the atom rearrangement to a direction parallel to the aforementioned interface does not happen at all, and especially therefore, the aforementioned antiferromagnetism layer is not metamorphosing suitable for a superlattice from an irregular grid by the interface. Therefore, a switched connection magnetic field will become small.
[0141] In addition, as for the interior angle theta between the aforementioned twin boundary and the aforementioned interface (refer to drawing 28 and drawing 31), in this invention, it is desirable that it is 76 degrees or less at 68 degrees or more. Incidentally the aforementioned interior angle theta of about 68 degrees and drawing 31 of the aforementioned interior angle of drawing 28 was about 75 degrees. The equivalent crystal face expressed in the direction where the aforementioned antiferromagnetism layer is parallel to the aforementioned interface that it is this within the limits as [111] sides carries out priority orientation. It is still more desirable that the equivalent crystal face expressed as [111] sides is carrying out priority orientation also of the aforementioned fixed magnetic layer 3. Resistance rate of change can be more effectively raised by this.
[0142] Moreover, it sets, after heat-treating by forming the antiferromagnetism layer 4 and the fixed magnetic layer 3 in this invention. If obtained as a diffraction pattern which observes the crystal

orientation of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 with a transparency electron-diffraction image, and this transparency electron-diffraction image explains below The crystal orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3 The same equivalent crystal face as a direction parallel to the interface of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 carries out priority orientation. And it is possible to presume what has turned to the direction which exists in the aforementioned crystal face, and where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.

[0143] In this invention, incidence of the interface and parallel shell electron ray (beam) of the antiferromagnetism layer 4 and the fixed magnetic layer 3 is carried out first, and a transparency electron-diffraction image is obtained about each of the antiferromagnetism layer 4 and the fixed magnetic layer 3.

[0144] In the transparency electron-diffraction image of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3, the diffraction mottle corresponding to the reciprocal-lattice point equivalent to each crystal face of each layer appears. The reciprocal-lattice point (= diffraction mottle) describing above is the crystal face expressed with Miller indices, for example, the reciprocal-lattice point describing above is a field (110) etc.

[0145] Next, indexing is performed to the aforementioned diffraction mottle. Since the distance r from a beam zero to a diffraction mottle is in inverse proportion to a lattice spacing d, d can be known by measuring r. Since the spacing of each crystal plane {hkl}, such as PtMn, and CoFe, NiFe, is known to some extent, it can carry out indexing {hkl} hkl [equivalent to each diffraction mottle] Becoming. Moreover, the transparency electron-diffraction figure which was observed or calculated to various kinds of directions of the crystal grain of single crystal structure and by which specific indexing which {hkl} Becomes each diffraction mottle was made is carried by the reference of a common transparency electron-diffraction image. Using such reference, the diffraction mottle obtained from the transparency electron-diffraction image of the above-mentioned antiferromagnetism layer 4 and the fixed magnetic layer 3 distinguishes [the same as that of the diffraction mottle of which crystal face in the case of single crystal structure, or] whether it is similar, and performs the same indexing as the case of the aforementioned single crystal {hkl} for every diffraction mottle according to each.

[0146] And the beam zeros which appeared in the transparency electron-diffraction image of the above-mentioned antiferromagnetism layer 4 and the transparency electron-diffraction image of the fixed magnetic layer 3 are made in agreement, and each diffraction figure is piled up.

[0147] Or a transparency electron-diffraction image is obtained in the range in which an electron ray is simultaneously irradiated by both diamagnetism layer 4 and fixed magnetic layer 3.

[0148] The diffraction mottle which is located in the direction of thickness when the indexing same among the aforementioned diffraction mottles at the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 is made in this invention and it sees from a beam zero and which shows a certain crystal face, The first imaginary line which connected the aforementioned beam zero is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer (** type view of the diffraction figure which shows drawing 16 and 18 reference; drawing 16 to a transparency electron-diffraction image, and shows drawing 18 to drawing 16). This means that the equivalent crystal face as the direction of a film surface with same aforementioned antiferromagnetism layer 4 and fixed magnetic layer 3 is carrying out priority orientation.

[0149] The second imaginary line which connected the diffraction mottle which furthermore shows a certain crystal face located in the direction of [other than the aforementioned thickness direction] by this invention when the same indexing is made and it sees from the aforementioned beam zero, and the aforementioned beam zero is mutually shifted in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer (drawing 16 , 18 references). About the crystal face which does not carry out orientation in the direction parallel to this, i.e., a film surface, it means that it is not an parallel relation mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3. Or when it sees from the aforementioned beam zero, the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction] and which shows a certain crystal face is not an parallel relation mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3 in the state of appearing only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.

[0150] In this invention, a clearly different diffraction figure from the example of comparison shown in drawing 17 and 19 (** type view of the diffraction figure which shows drawing 17 to a transparency electron-diffraction image, and shows drawing 19 to drawing 17) can be obtained. It is because the

second imaginary line which connected the diffraction mottle which is located in the direction of other than the aforementioned thickness direction], and which shows a certain crystal face, and the aforementioned beam zero with drawing 17 and the example of comparison shown in 19 when the same indexing was made and it saw from the aforementioned beam zero is mutually in agreement by the diffraction figure of the antiferromagnetism layer 4 and the fixed magnetic layer 3.

[0151] In this invention, when a transparency electron-diffraction image as shown in drawing 16 is obtained, the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and can guess that they are the thing which exists in the aforementioned crystal face and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.

[0152] Therefore, if it is the spin bulb film with which the above-mentioned transparency electron-diffraction image is obtained, the antiferromagnetism layer 4 has caused the suitable rule transformation in the stage which heat-treated, and it is possible to acquire a big switched connection magnetic field.

[0153] In addition, as for the diffraction mottle located in the aforementioned thickness direction in this invention, it is desirable that the equivalent crystal face typically expressed as {111} sides is shown.

[0154] Moreover, if obtained as a diffraction pattern which observes the crystal orientation of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 with a transparency electron-diffraction image from direction where the above is another, and this transparency electron-diffraction image explains below by this invention The same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and can guess that they are the thing which moreover exists in the aforementioned crystal face and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.

[0155] That is, in this invention, incidence of the electron ray (beam) is carried out from the interface and perpendicular direction of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and a transparency electron-diffraction image is simultaneously obtained about each of the antiferromagnetism layer 4 and the fixed magnetic layer 3 (drawing 21 referring-to-; drawing 20 and drawing 20 the ** type view of the diffraction figure of the antiferromagnetism layer 4 and drawing 21 ** type view of the diffraction figure of the fixed magnetic layer 3).

[0156] In the transparency electron-diffraction image of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3, the diffraction mottle of the same reciprocal-lattice side appears. The crystal face [parallel, the aforementioned reciprocal-lattice side, i.e., the plane of projection of an electron-diffraction image, to the crystal face perpendicular to an incidence electron ray for example,] parallel to the aforementioned reciprocal-lattice side is a field (111) etc. In addition, in this invention, a direction perpendicular to the aforementioned interface is the direction of the equivalent crystallographic axis typically expressed as <111> directions, or, as for the crystal face parallel to the aforementioned interface of an antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is the equivalent crystal face typically expressed as [111] sides.

[0157] Next, with reference to the reference of the transparency electron-diffraction image in the case of single crystal structure etc., indexing is performed to the aforementioned diffraction mottle. Since there is a difference in a lattice constant, i.e., the difference in a lattice spacing, in the antiferromagnetism layer 4 and the fixed magnetic layer 3, the transparency electron-diffraction spot of the antiferromagnetism layer 4 and the transparency electron-diffraction spot of the fixed magnetic layer 3 can be easily distinguished by the difference in distance with the beam zero of those spots (refer to drawing 22).

[0158] In this invention, the imaginary line (imaginary line **, imaginary line **, and imaginary line ** and imaginary line **) to which the same indexing connected ****** and from a certain diffraction mottle to the beam zero with the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 among the aforementioned diffraction mottles is in the state where it shifted mutually in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer (refer to drawing 22). This means having turned to the direction which exists in the crystal face which carried out orientation and where the directions of a certain same equivalent crystallographic axis differ mutually by the

antiferromagnetism
layer 4 and the fixed magnetic layer 3 in the direction parallel to a film surface. Or the diffraction mottle to which a certain indexing was carried out among the aforementioned diffraction mottles means having turned to a direction which is mutually different with the antiferromagnetism layer 4 and the fixed magnetic layer 3 also in the state of appearing only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0159] It turns out that the transparency electron-diffraction images of the example of comparison which shows the transparency electron-diffraction image in the above-mentioned this invention to drawing 23 or drawing 25 (** type view on top of which the ** type view of the diffraction figure of an antiferromagnetism layer and drawing 24 laid the ** type view of the diffraction figure of a fixed magnetic layer, and, as for drawing 25 , drawing 23 laid drawing 23 and drawing 24) differ clearly.
[0160] As shown in drawing 25 , imaginary line **** connected from a certain diffraction mottle to the beam zero is because it is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.
[0161] Although the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3 in this invention when the transparency electron-diffraction image shown in drawing 20 or drawing 22 is obtained, a part of a certain same equivalent crystallographic axis [at least] is conjectured to have turned to a direction which exists in the aforementioned crystal face and which is mutually different by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0162] Therefore, if it is the spin bulb film with which the above-mentioned transparency electron-diffraction image is obtained, the antiferromagnetism layer 4 has caused the suitable rule transformation in the stage which heat-treated, and it is possible to acquire a big switched connection magnetic field.
[0163] Although the focus of the crystal orientation of the spin bulb type thin film in this invention, the grain boundary, and the twin boundary was explained as mentioned above, in order to have obtained such crystal orientation, the grain boundary, and the twin boundary, when the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are formed, the atom of the aforementioned antiferromagnetism layer 4 must be made not to be restrained by the crystal structure of the aforementioned fixed magnetic layer 3 firmly. In order to weaken restraint, it is desirable that it is in the so-called disconformity state by the interface of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0164] A disconformity state needs to extend the lattice constant of the aforementioned antiferromagnetism layer 4 as compared with the lattice constant of the aforementioned fixed magnetic layer 3 to make such a disconformity state, although the array of the atom of the antiferromagnetism layer 4 and the array of the atom of the fixed magnetic layer 3 say the thing in the state where it does not correspond to 1 to 1 by the aforementioned interface.
[0165] In addition to it, the aforementioned antiferromagnetism layer 4 must cause a suitable rule transformation with heat treatment. Even if an interface with the aforementioned fixed magnetic layer 3 is in a disconformity state, when the aforementioned antiferromagnetism layer 4 does not cause a rule transformation, a switched connection magnetic field will become low after all.
[0166] It is thought that rationalization of whether to cause the disconformity state in the above-mentioned membrane formation stage and a rule transformation has the large place depended on the composition ratio and membrane formation conditions of each composition element which constitutes the antiferromagnetism layer 4.
[0167] It is desirable to set the element X of the antiferromagnetism layer 4 or atomic % of element X+X' below to 60 (at%) more than 45 (at%) in this invention. This changes an interface with the fixed magnetic layer 3 into a disconformity state in a membrane formation stage, and, moreover, it is guessed that the aforementioned antiferromagnetism layer 4 is what causes a suitable rule transformation with heat treatment.
[0168] By using the antiferromagnetism layer 4 which is above-mentioned composition within the limits, and was formed, and in the spin bulb type thin film after heat treatment Priority orientation of the same equivalent crystal face as a direction parallel to a film surface is carried out for the crystal orientation of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3. And it is possible to make it suitable in the direction which exists in the aforementioned crystal face of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 and which is mutually different in a part of a certain same equivalent crystallographic axis [at least]. Moreover, the grain boundary of the aforementioned antiferromagnetism layer 4 and the grain boundary of the fixed magnetic layer 3 can be changed into a discontinuous state by a part of interface [at least].
Moreover, [111] plane orientation of the aforementioned antiferromagnetism layer 4 can be carried

out, and the twin boundary further formed in the aforementioned antiferromagnetism layer 4 can be formed by aforementioned being the interface and being un-parallel. According to the experimental result later mentioned as it is above-mentioned composition within the limits, it is possible to acquire the switched connection magnetic field more than 1.58x104 (A/m).
[0169] Moreover, it is desirable to set atomic % of the aforementioned element X or element X+X' below to 56.5 (at%) in this invention above 49 (at%). It is possible for this to acquire the switched connection magnetic field more than 7.9x104 (A/m).
[0170] Moreover, the aforementioned membrane formation conditions important for forming a disconformity state are Ar gas pressure used in case the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are formed, heat treatment conditions, the substrate at the time of forming the aforementioned antiferromagnetism layer 4 further and the distance between targets, substrate temperature and substrate bias voltage, membrane formation speed, etc.
[0171] In this invention, for example, the aforementioned Ar gas pressure is set to 3mTorr(s). Moreover, heat treatment temperature is made into 300 degrees C or less above 200 degrees C, and heat treatment among a magnetic field is carried out for heat treatment time in the vacuum of 10 to 6 or less Torrs in 2 hours or more. Moreover, distance between the aforementioned substrate and a target is set to 80mm.
[0172] Moreover, in the spin bulb type thin film which has the above-mentioned crystal orientation in this invention, it is possible to change a part of interface [at least] of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 into a disconformity state after heat treatment.
[0173] Moreover, the crystal orientation of the above-mentioned antiferromagnetism layer 4 and the above-mentioned fixed magnetic layer 3 and a transparency electron-diffraction image are observed also between the seed layer 22 and the antiferromagnetism layer 4. That is, the same equivalent crystal face as a direction parallel to a film surface carried out priority orientation between the aforementioned seed layer 22 and the antiferromagnetism layer 4, and a part of a certain same equivalent crystallographic axis [at least] has turned to a direction which moreover exists in the aforementioned crystal face and which is mutually different in the aforementioned seed layer 22 and the antiferromagnetism layer 4.
[0174] Moreover, in the cross section of a direction parallel to the direction of thickness, a part of grain boundary of the aforementioned seed layer 22 and grain boundary [at least] of the antiferromagnetism layer 4 are in the discontinuous state.
[0175] If such crystal orientation and the grain boundary exist between the seed layer 22 and the antiferromagnetism layer 4, in the interface of the aforementioned seed layer 22 and the antiferromagnetism layer 4, at least a part tends to maintain a disconformity state, therefore the aforementioned antiferromagnetism layer 4 will have caused the suitable rule transformation, without being restrained by the crystal structure of the aforementioned seed layer 22, and a still bigger switched connection magnetic field will be acquired.
[0176] Moreover, it is desirable to form the thickness of the aforementioned antiferromagnetism layer 4 within the limits of 7nm - 30nm in this invention. Thus, in this invention, even if it makes thickness of the aforementioned antiferromagnetism layer 4 thin, a still more suitable switched connection magnetic field can be generated.
[0177] Drawing 2 is the fragmentary sectional view showing the structure of another spin bulb type thin film. In this spin bulb type thin film, the laminating of the fixed magnetic layer 3, the antiferromagnetism layer 4, and protective layer 7 which consist of the lower shell ground layer 6, the free magnetic layer 1 which consists of the NiFe alloy film 9 and the Co film 10, the nonmagnetic interlayer 2 and the Co film 11, the Ru film 12, and the Co film 13 is carried out. And the hard bias layers 5 and 5 and conductive layers 8 and 8 are formed in the both sides of the aforementioned cascade screen.
[0178] In addition, it is the same as the spin bulb type thin film explained to drawing 1 about the quality of the material of each class etc.
[0179] In the spin bulb type thin film shown in drawing 2 , the same equivalent crystal face as a direction parallel to a film surface carried out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and they have turned to the direction which exists in the aforementioned crystal face and where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0180] Moreover, when the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, an interface sets the grain boundary of the aforementioned antiferromagnetism layer 4, and the grain

boundary of the aforementioned fixed magnetic layer 3 in part at least, and they are in the discontinuous state.
[0181] For this reason, a part of aforementioned interface [at least] maintains a disconformity state, the suitable rule transformation is made by heat treatment, and the aforementioned antiferromagnetism layer 4 can acquire a big switched connection magnetic field.
[0182] In addition, it is desirable that the equivalent crystal face typically expressed in the direction where the antiferromagnetism layer 4 and the fixed magnetic layer 3 are parallel to a film surface as [111] sides is carrying out priority orientation. Moreover, it is desirable to have turned to the direction where the directions of the equivalent crystallographic axis typically expressed as <110> directions in the aforementioned crystal face differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0183] Moreover, although it is difficult to carry out [111] plane orientation of the aforementioned antiferromagnetism layer 4 compared with the case where a laminating is carried out to the order of a seed layer, the antiferromagnetism layer 4, and the fixed magnetic layer 3 when the aforementioned antiferromagnetism layer 4 is formed on the fixed magnetic layer 3 like this operation gestalt, it is possible to make the aforementioned antiferromagnetism layer 4 into [111] plane orientation by control of membrane formation conditions etc. And by this invention, twin crystal is formed in the aforementioned antiferromagnetism layer 4 in part at least in this case, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. While being able to raise resistance rate of change by this, the aforementioned antiferromagnetism layer 4 is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire a big switched connection magnetic field. In addition, as for the interior angle between the aforementioned twin boundary and an interface, it is desirable that it is 76 degrees or less at 68 degrees or more.
[0184] moreover, in the spin bulb type thin film shown in drawing 2 In the transparency electron-diffraction image of the antiferromagnetism layer 4 which was made to carry out incidence of the parallel shell electron ray (beam) to the aforementioned interface, and was obtained, and the fixed magnetic layer 3 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The diffraction mottle which is located in the direction of thickness when the indexing same among the aforementioned diffraction mottles at the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 is made and it sees from a beam zero and which shows a certain crystal face, The first imaginary line which connected the aforementioned beam zero is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.
[0185] And the second imaginary line which connected with this invention the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction], and which shows a certain crystal face, and the aforementioned zero when the same indexing was made and it saw from the aforementioned beam zero is mutually shifted in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or when it sees from the aforementioned beam zero, the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction] and which shows a certain crystal face appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0186] As for the diffraction mottle located in the aforementioned thickness direction, in the above-mentioned case, it is desirable that it is the equivalent crystal face typically expressed as {111} sides.
[0187] or in the spin bulb type thin film shown in drawing 2 In the transparency electron-diffraction image of the antiferromagnetism layer 4 which was made to carry out incidence of the electron ray (beam), and was obtained from the aforementioned interface and the perpendicular direction, and the fixed magnetic layer 3 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The imaginary line by which the same indexing was made by the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 and which connected from a certain diffraction mottle to the beam zero is mutually shifted among the aforementioned diffraction mottles in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or the diffraction mottle to which a certain indexing was carried out among the aforementioned diffraction mottles appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0188] In the above-mentioned case, a direction perpendicular to the aforementioned interface is the direction of the equivalent crystallographic axis typically expressed as <111> directions, or, as for the crystal face parallel to the aforementioned interface of an antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is the equivalent crystal face typically expressed as [111]

sides.
[0189] If the above transparency electron-diffraction images are obtained, the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and can guess that they are the thing which moreover exists in the aforementioned crystal face and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0190] And the aforementioned antiferromagnetism layer 4 has caused the suitable rule transformation with heat treatment as it is the spin bulb type thin film which has the above-mentioned transparency electron-diffraction image, and a big switched connection magnetic field is acquired compared with the former.
[0191] Moreover, as for the element X which constitutes the antiferromagnetism layer 4, or the composition ratio of element X+X', in the spin bulb type thin film shown in drawing 2 , it is desirable that it is below 60 (at%) more than 45 (at%). It is possible for this to acquire the switched connection magnetic field more than 1.58x104 (A/m).
[0192] Moreover, as for the aforementioned element X or the composition ratio of element X+X', in this invention, it is desirable that it is below 57 (at%) more than 49 (at%). It is possible for this to acquire the switched connection magnetic field more than 7.9x104 (A/m).
[0193] Next, drawing 3 is the fragmentary sectional view showing the structure of another spin bulb type thin film in this invention.
[0194] In drawing 3 , the laminating of the lower shell ground layer 6, the seed layer 22, the antiferromagnetism layer 4, the fixed magnetic layer 3, the nonmagnetic interlayer 2, and the free magnetic layer 1 is carried out.
[0195] As for the aforementioned ground layer 6, it is desirable to be formed by at least one or more sorts of elements among Ta, Hf, Nb, Zr, Ti, Mo, and W.
[0196] Moreover, as for the aforementioned seed layer 22, it is desirable that the equivalent crystal face with which the crystal structure is moreover typically expressed in the direction parallel to an interface with the antiferromagnetism layer 4 as [111] sides by mainly consisting of a face-centered cubic is carrying out priority orientation. In addition, it is the same as that of what was explained by drawing 1 about the quality of the material of the aforementioned seed layer 22 etc.
[0197] By forming the aforementioned seed layer 22 in the bottom of the antiferromagnetism layer 4, the same equivalent crystal face as the aforementioned seed layer 22 carries out priority orientation also of the antiferromagnetism layer 4 formed on the aforementioned seed layer 22, the fixed magnetic layer 3, the nonmagnetic interlayer 2, and the free magnetic layer 1 in the direction parallel to a film surface.
[0198] Moreover, although the fixed magnetic layer 3 is formed by three layer membranes of the Co films 11 and 13 and the Ru film 12, drawing 3 is available, even if other quality of the materials may be used and it is formed not by three layer membranes but by the monolayer.
[0199] Moreover, although the free magnetic layer 1 is formed by the two-layer film of the NiFe alloy film 9 and the Co film 10, even if other quality of the materials may be used and it is formed not by the two-layer film but by the monolayer, it is not cared about.
[0200] In the spin bulb type thin film shown in drawing 3 , the same equivalent crystal face as a direction parallel to a film surface carried out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and they have turned to the direction which moreover exists in the aforementioned crystal face and where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0201] Moreover, when the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, the grain boundary of the aforementioned antiferromagnetism layer 4 and the grain boundary of the aforementioned fixed magnetic layer 3 are in the discontinuous state by a part of aforementioned interface [at least].
[0202] For this reason, a part of aforementioned interface [at least] maintains a disconformity state, the suitable rule transformation is made by heat treatment, and the aforementioned antiferromagnetism layer 4 can acquire a big switched connection magnetic field.
[0203] In addition, it is desirable that the equivalent crystal face typically expressed in the direction parallel to antiferromagnetism layer 4 and fixed magnetic layer 3 film surface as [111] sides is carrying out priority orientation. Moreover, it is desirable to have turned to the direction where the directions of the equivalent crystallographic axis typically expressed as <110> directions in the aforementioned crystal face differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3.

[0204] Moreover, the equivalent crystal face typically expressed with this invention in the direction where the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned antiferromagnetism layer 4 in part at least, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. While being able to raise resistance rate of change by this, the aforementioned antiferromagnetism layer 4 is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire a big switched connection magnetic field. In addition, as for the interior angle between the aforementioned twin boundary and an interface, it is desirable that it is 76 degrees or less at 68 degrees or more.
[0205] moreover, in the spin bulb type thin film shown in drawing 3 In the transparency electron-diffraction image of the antiferromagnetism layer 4 which was made to carry out incidence of the parallel shell electron ray (beam) to the aforementioned interface, and was obtained, and the fixed magnetic layer 3 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The diffraction mottle which is located in the direction of thickness when the indexing same among the aforementioned diffraction mottles at the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 is made and it sees from a beam zero and which shows a certain crystal face, The first imaginary line which connected the aforementioned beam zero is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.
[0206] And the second imaginary line which connected with this invention the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction], and which shows a certain crystal face, and the aforementioned beam zero when the same indexing was made and it saw from the aforementioned beam zero is mutually shifted in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.
Moreover, when it sees from the aforementioned beam zero, the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction] and which shows a certain crystal face appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0207] As for the diffraction mottle located in the aforementioned thickness direction, in the above-mentioned case, it is desirable that it is the equivalent crystal face typically expressed as {111} sides.
[0208] or in the spin bulb type thin film shown in drawing 3 In the transparency electron-diffraction image of the antiferromagnetism layer 4 which was made to carry out incidence of the electron ray (beam), and was obtained from the aforementioned interface and the perpendicular direction, and the fixed magnetic layer 3 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The imaginary line by which the same indexing was made by the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 and which connected from a certain diffraction mottle to the beam zero is mutually shifted among the aforementioned diffraction mottles in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or the diffraction mottle to which a certain indexing was carried out among the aforementioned diffraction mottles appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0209] In the above-mentioned case, a direction perpendicular to the aforementioned interface is the direction of the equivalent crystallographic axis typically expressed as <111> directions, or, as for the crystal face parallel to the aforementioned interface of an antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is the equivalent crystal face typically expressed as [111] sides.
[0210] If the above transparency electron-diffraction images are obtained, the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and can guess that they are the thing which moreover exists in the aforementioned crystal face and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3. The aforementioned antiferromagnetism layer 4 has caused the suitable rule transformation with heat treatment as it is the spin bulb type thin film which has the above-mentioned transparency electron-diffraction image, and a big switched connection magnetic field is acquired compared with the former.
[0211] Moreover, as for the element X which constitutes the antiferromagnetism layer 4, or the composition ratio of element X+X', in the spin bulb type thin film shown in drawing 3 , it is desirable that it is below 60 (at%) more than 45 (at%). It is possible for this to acquire the switched connection

magnetic field more than 1.58x104 (A/m).
[0212] Moreover, as for the aforementioned element X or the composition ratio of element X+X', in this invention, it is desirable that it is below 56.5 (at%) more than 49 (at%). It is possible for this to acquire the switched connection magnetic field more than 7.9x104 (A/m).
[0213] Moreover, as shown in drawing 3 , on the aforementioned free magnetic layer 1, the interval of the width of recording track Tw is opened in the direction of the width of recording track (the direction of illustration X), and the exchange bias layers (antiferromagnetism layer) 16 and 16 are formed.
[0214] In addition, this exchange bias layer 16 is a X-Mn alloy (however, X). they are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os -- desirable -- a PtMn alloy or a X-Mn-X' alloy (however, X') Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements -- one sort or two sorts or more of elements -- it is -- it is formed
[0215] In this invention, the same equivalent crystal face as a direction parallel to a film surface carried out priority orientation of the aforementioned exchange bias layer 16 and the free magnetic layer 1, some [at least] directions of a certain same equivalent crystallographic axis are with the aforementioned exchange bias layer 16 and the free magnetic layer 1, and they have turned to a mutually different direction which moreover exists in the aforementioned crystal face.
[0216] Moreover, when the aforementioned exchange bias layer 16 and the free magnetic layer 1 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, an interface sets the grain boundary of the aforementioned exchange bias layer 16, and the grain boundary of the aforementioned free magnetic layer 1 in part at least, and they are in the discontinuous state.
[0217] For this reason, a part of aforementioned interface [at least] maintains a disconformity state, the suitable rule transformation is made by heat treatment, and the aforementioned exchange bias layer 16 can acquire a big switched connection magnetic field.
[0218] In addition, as for the exchange bias layer 16 and the free magnetic layer 1, it is desirable that the equivalent crystal face typically expressed in the direction parallel to a film surface as [111] sides is carrying out priority orientation. Moreover, it is desirable to have turned to the direction where the directions of the equivalent crystallographic axis typically expressed as <110> directions in the aforementioned crystal face differ mutually by the exchange bias layer 16 and the free magnetic layer 1.
[0219] Moreover, the equivalent crystal face typically expressed with this invention in the direction where the aforementioned exchange bias layer 16 is parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned exchange bias layer 16 in part at least, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. For this reason, the aforementioned exchange bias layer 16 is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire
a big switched connection magnetic field. In addition, as for the interior angle between the aforementioned twin boundary and an interface, it is desirable that it is 76 degrees or less at 68 degrees or more.
[0220] moreover, in the spin bulb type thin film shown in drawing 3 In the transparency electron-diffraction image of the exchange bias layer 16 and the free magnetic layer 1 which were made to carry out incidence of the parallel shell electron ray (beam) to the aforementioned interface, and were obtained The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The diffraction mottle which is located in the direction of thickness when the indexing same among the aforementioned diffraction mottles at the diffraction figure of the exchange bias layer 16 and the diffraction figure of the free magnetic layer 1 is made and it sees from a beam zero and which shows a certain crystal face, The first imaginary line which connected the aforementioned beam zero is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.
[0221] And the second imaginary line which connected with this invention the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction], and which shows a certain crystal face, and the aforementioned beam zero when the same indexing was made and it saw from the aforementioned beam zero is mutually shifted in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or when it sees from the aforementioned beam zero, the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction] and which shows a certain crystal face appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0222] As for the diffraction mottle located in the aforementioned thickness direction, in the

above-mentioned case, it is desirable that it is the equivalent crystal face typically expressed as {111} sides.
[0223] or in the spin bulb type thin film shown in drawing 3 In the transparency electron-diffraction image of the exchange bias layer 16 and the free magnetic layer 1 which were made to carry out incidence of the electron ray (beam), and were obtained from the aforementioned interface and the perpendicular direction The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The imaginary line by which the same indexing was made by the diffraction figure of the exchange bias layer 16 and the diffraction figure of the free magnetic layer 1 and which connected from a certain diffraction mottle to the beam zero is mutually shifted among the aforementioned diffraction mottles in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or the diffraction mottle to which a certain indexing was carried out among the aforementioned diffraction mottles appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0224] In the above-mentioned case, a direction perpendicular to the aforementioned interface is the direction of the equivalent crystallographic axis typically expressed as <111> directions, or, as for the crystal face parallel to the aforementioned interface of an antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is the equivalent crystal face typically expressed as [111] sides.
[0225] The same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the exchange bias layer 16 and the free magnetic layer 1 to it being the spin bulb type thin film which has the above transparency electron-diffraction images, and it is guessed that it is the thing which moreover exists in the aforementioned crystal face and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned exchange bias layer 16 and the free magnetic layer 1. And in the spin bulb type thin film which has the aforementioned transparency electron-diffraction image, the aforementioned exchange bias layer 16 has caused the suitable rule transformation with heat treatment, and a big switched connection magnetic field is acquired compared with the former.
[0226] At the both-sides edge of the aforementioned free magnetic layer 1, the free magnetic layer 1 is formed into a single magnetic domain in the direction of illustration X by the switched connection magnetic field between the exchange bias layers 16, and magnetization of the width-of-recording-track Tw field of the free magnetic layer 1 is arranged with the grade which reacts to an external magnetic field in the direction of illustration X at fitness.
[0227] Thus, with the formed single spin bulb type magnetoresistance-effect element, magnetization of the width-of-recording-track Tw field of the free magnetic layer 1 changes with the external magnetic fields of the direction of illustration Y in the direction of illustration Y from illustration X. Electric resistance changes by the relation between change of the direction of magnetization within this free magnetic layer 1, and the fixed magnetization direction (the direction of illustration Y) of the fixed magnetic layer 3, and the leak magnetic field from a record medium is detected by the voltage change based on this electric resistance value change.
[0228] Drawing 4 is the fragmentary sectional view showing the structure of other spin bulb type thin films in this invention.
[0229] In the spin bulb type thin film shown in drawing 4 , the seed layer 22 of the couple which opened the interval of the width of recording track Tw in the direction of the width of recording track (the direction of illustration X) is formed, and the exchange bias layers 16 and 16 are formed on the aforementioned seed layer 22.
[0230] It is buried by the insulating layer 17 formed by the insulating material of SiO2 or aluminum2O3 grade between the seed layer 22 of the aforementioned couple, and the exchange bias layer 16.
[0231] And the free magnetic layer 1 is formed on the aforementioned exchange bias layer 16 and the insulating layer 17.
[0232] It is formed with a X-Mn alloy or a X-Mn-X' alloy, and as for the aforementioned element X or the composition ratio of element X+X', it is desirable that it is below 60 (at%) more than 45 (at%), and the aforementioned exchange bias layer 16 is below 56.5 (at%) more than 49 (at%) more preferably.
[0233] By heat-treating, the aforementioned exchange bias layer 16 cannot be restrained by the crystal structure of the free magnetic layer 1, but can cause a suitable rule transformation, and can acquire a big switched connection magnetic field compared with the former.
[0234] In this invention, after heat treatment, the same equivalent crystal face as a direction parallel to a film surface carried out priority orientation of the aforementioned exchange bias layer 16 and the free magnetic layer 1, and they have turned to the direction which moreover exists in the aforementioned crystal face and where a part of a certain same equivalent crystallographics axis [at

least] differ mutually by the aforementioned exchange bias layer 16 and the free magnetic layer 1.

[0235] Moreover, when the aforementioned exchange bias layer 16 and the free magnetic layer 1 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, an interface sets the grain boundary of the aforementioned exchange bias layer 16, and the grain boundary of the aforementioned free magnetic layer 1 in part at least, and they are in the discontinuous state.

[0236] For this reason, a part of aforementioned interface [at least] maintains a disconformity state, the suitable rule transformation is made by heat treatment, and the aforementioned exchange bias layer 16 can acquire a big switched connection magnetic field.

[0237] In addition, as for the exchange bias layer 16 and the free magnetic layer 1, it is desirable that the equivalent crystal face typically expressed in the direction parallel to a film surface as [111] sides is carrying out priority orientation. Moreover, it is desirable to have turned to the direction where the directions of the equivalent crystallographic axis typically expressed as <110> directions in the aforementioned crystal face differ mutually by the exchange bias layer 16 and the free magnetic layer 1.

[0238] Moreover, the equivalent crystal face typically expressed with this invention in the direction where the aforementioned exchange bias layer 16 is parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned exchange bias layer 16 in part at least, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. For this reason, the aforementioned exchange bias layer 16 is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire a big switched connection magnetic field. In addition, as for the interior angle between the aforementioned twin boundary and an interface, it is desirable that it is 76 degrees or less at 68 degrees or more.

[0239] moreover, in the spin bulb type thin film shown in drawing 4 In the transparency electron-diffraction image of the exchange bias layer 16 and the free magnetic layer 1 which were made to carry out incidence of the parallel shell electron ray (beam) to the aforementioned interface, and were obtained The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The diffraction mottle which is located in the direction of thickness when the indexing same among the aforementioned diffraction mottles at the diffraction figure of the exchange bias layer 16 and the diffraction figure of the free magnetic layer 1 is made and it sees from a beam zero and which shows a certain crystal face, The first imaginary line which connected the aforementioned beam zero is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.

[0240] And the second imaginary line which connected with this invention the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction], and which shows a certain crystal face, and the aforementioned beam zero when the same indexing was made and it saw from the aforementioned zero is mutually shifted in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or when it sees from the aforementioned beam zero, the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction] and which shows a certain crystal face appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.

[0241] As for the diffraction mottle located in the aforementioned thickness direction, in the above-mentioned case, it is desirable that the equivalent crystal face typically expressed as {111} sides is shown.

[0242] or in the spin bulb type thin film shown in drawing 4 In the transparency electron-diffraction image of the exchange bias layer 16 and the free magnetic layer 1 which were made to carry out incidence of the electron ray (beam), and were obtained from the aforementioned interface and the perpendicular direction The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The imaginary line by which the same indexing was made by the diffraction figure of the exchange bias layer 16 and the diffraction figure of the free magnetic layer 1 and which connected from a certain diffraction mottle to the beam zero is mutually shifted among the aforementioned diffraction mottles in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or the diffraction mottle to which a certain indexing was carried out among the aforementioned diffraction mottles appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.

[0243] In the above-mentioned case, a direction perpendicular to the aforementioned interface is the direction of the equivalent crystallographic axis typically expressed as <111> directions, or, as for the crystal face parallel to the aforementioned interface of an antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is the equivalent crystal face typically expressed as [111]

sides.
[0244] If the above transparency electron-diffraction images are obtained, the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the exchange bias layer 16 and the free magnetic layer 1, and can guess that they are the thing which exists in the aforementioned crystal face and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned exchange bias layer 16 and the free magnetic layer 1. And the aforementioned exchange bias layer 16 has caused the suitable rule transformation with heat treatment as it is the above-mentioned spin bulb type thin film, and a big switched connection magnetic field is acquired compared with the former.
[0245] At the both-sides edge of the aforementioned free magnetic layer 1, a single magnetic domain is formed in the direction of illustration X by the switched connection magnetic field between the exchange bias layers 16, and magnetization of the width-of-recording-track Tw field of the free magnetic layer 1 is arranged with the grade which reacts to an external magnetic field in the direction of illustration X at fitness.
[0246] As shown in drawing 4 , the nonmagnetic interlayer 2 is formed on the aforementioned free magnetic layer 1, and on the aforementioned nonmagnetic interlayer 2, the fixed magnetic layer 3 is formed further. Furthermore on the aforementioned fixed magnetic layer 3, the antiferromagnetism layer 4 is formed.
[0247] In this invention, after heat treatment, the same equivalent crystal face as a direction parallel to a film surface carried out priority orientation of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3, and they have turned to the direction which moreover exists in the aforementioned crystal face and where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0248] Moreover, when the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, an interface sets the grain boundary of the aforementioned antiferromagnetism layer 4, and the grain boundary of the aforementioned fixed magnetic layer 3 in part at least, and they are in the discontinuous state.
[0249] For this reason, a part of aforementioned interface [at least] maintains a disconformity state, the suitable rule transformation is made by heat treatment, and the aforementioned antiferromagnetism layer 4 can acquire a big switched connection magnetic field.
[0250] In addition, it is desirable that the equivalent crystal face typically expressed in the direction parallel to antiferromagnetism layer 4 and fixed magnetic layer 3 film surface as [111] sides is carrying out priority orientation. Moreover, it is desirable to have turned to the direction where the directions of the equivalent crystallographic axis typically expressed as <110> directions in the aforementioned crystal face differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0251] Moreover, the equivalent crystal face typically expressed with this invention in the direction where the aforementioned antiferromagnetism layer 4 is parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned antiferromagnetism layer 4 in part at least, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. While being able to raise resistance rate of change by this, the aforementioned antiferromagnetism layer 4 is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire a big switched connection magnetic field. In addition, as for the interior angle between the aforementioned twin boundary and an interface,
it is desirable that it is 76 degrees or less at 68 degrees or more.
[0252] moreover, in the spin bulb type thin film shown in drawing 4 In the transparency electron-diffraction image of the anti-strong magnetic layer layer 4 which was made to carry out incidence of the parallel shell electron ray (beam) to the aforementioned interface, and was obtained, and the fixed magnetic layer 3 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The diffraction mottle which is located in the direction of thickness when the indexing same among the aforementioned diffraction mottles at the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 is made and it sees from a beam zero and which shows a certain crystal face, The first imaginary line which connected the aforementioned beam zero is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.
[0253] And the second imaginary line which connected with this invention the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction], and which

shows a certain crystal face, and the aforementioned beam zero when the same indexing was made and it saw from the aforementioned beam zero is mutually shifted in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or when it sees from the aforementioned beam zero, the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction] and which shows a certain crystal face appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0254] As for the diffraction mottle located in the aforementioned thickness direction, in the above-mentioned case, it is desirable that the equivalent crystal face typically expressed as {111} sides is shown.
[0255] or in the spin bulb type thin film shown in drawing 4 In the transparency electron-diffraction image of the antiferromagnetism layer 4 which was made to carry out incidence of the electron ray (beam), and was obtained from the aforementioned interface and the perpendicular direction, and the fixed magnetic layer 3 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The imaginary line by which the same indexing was made by the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 and which connected from a certain diffraction mottle to the beam zero is mutually shifted among the aforementioned diffraction mottles in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or the diffraction mottle to which a certain indexing was carried out among the aforementioned diffraction mottles appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.
[0256] In the above-mentioned case, a direction perpendicular to the aforementioned interface is the direction of the equivalent crystallographic axis typically expressed as <111> directions, or, as for the crystal face parallel to the aforementioned interface of an antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is the equivalent crystal face typically expressed as [111] sides.
[0257] If the above transparency electron-diffraction images are obtained, the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and what has turned to the direction which moreover exists in the aforementioned crystal face, and where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3 can be conjectured. And the aforementioned antiferromagnetism layer 4 has caused the suitable rule transformation with heat treatment as it is the spin bulb type thin film which has the above-mentioned transparency electron-diffraction image, and a big switched connection magnetic field is acquired compared with the former.
[0258] Drawing 5 is the fragmentary sectional view showing the structure of the dual spin bulb type thin film in this invention.
[0259] As shown in drawing 5 , the laminating of the lower shell ground layer 6, the seed layer 22, the antiferromagnetism layer 4, the fixed magnetic layer 3, the nonmagnetic interlayer 2, and the free magnetic layer 1 is carried out continuously. The aforementioned free magnetic layer 1 is formed by three layer membranes, for example, consists of Co films 10 and 10 and a NiFe alloy film 9.
Furthermore on the aforementioned free magnetic layer 1, the laminating of the nonmagnetic interlayer 2, the fixed magnetic layer 3, the antiferromagnetism layer 4, and the protective layer 7 is carried out continuously.
[0260] Moreover, the laminating of the hard bias layers 5 and 5 and the conductive layers 8 and 8 is carried out to the both sides of the multilayer from the ground layer 6 to a protective layer 7. In addition, each class is formed with the same quality of the material as the quality of the material explained by drawing 1 .
[0261] The seed layer 22 is formed in the bottom of the antiferromagnetism layer 4 located in the illustration bottom rather than the free magnetic layer 1 in this example. As for the element X which furthermore constitutes the aforementioned antiferromagnetism layer 4, or the composition ratio of element X+X', it is desirable to be formed more than 45 (at%) above 60 (at%), and it is below 56.5 (at%) more than 49 (at%) more preferably.
[0262] And in this invention, the same equivalent crystal face as a direction parallel to the interface of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 carried out priority orientation of the crystal orientation of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 after heat treatment, and a part of a certain same equivalent crystallographic axis at least] has turned to a mutually different direction which exists in the aforementioned crystal face of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0263] Moreover, when the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, an

interface sets the grain boundary of the aforementioned antiferromagnetism layer 4, and the grain boundary of the aforementioned fixed magnetic layer 3 in part at least, and they are in the discontinuous state.
[0264] For this reason, a part of aforementioned interface [at least] maintains a disconformity state, the suitable rule transformation is made by heat treatment, and the aforementioned antiferromagnetism layer 4 can acquire a big switched connection magnetic field.
[0265] In addition, it is desirable that the equivalent crystal face typically expressed in the direction parallel to antiferromagnetism layer 4 and fixed magnetic layer 3 film surface as [111] sides is carrying out priority orientation. Moreover, it is desirable to have turned to the direction where the directions of the equivalent crystallographic axis typically expressed as <110> directions in the aforementioned crystal face differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0266] Moreover, the equivalent crystal face typically expressed with this invention in the direction where the aforementioned antiferromagnetism layer 4 is parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned antiferromagnetism layer 4 in part at least, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. While being able to raise resistance rate of change by this, the aforementioned antiferromagnetism layer 4 is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire a big switched connection magnetic field. In addition, as for the interior angle between the aforementioned twin boundary and an interface,
it is desirable that it is 76 degrees or less at 68 degrees or more.
[0267] Moreover, in the dual spin bulb type thin film shown in drawing 5 , the crystal orientation of the fixed magnetic layer 3 formed below the free magnetic layer 1 and not only the antiferromagnetism layer 4 but the whole cascade screen has the same crystal orientation as the above.
[0268] That is, in this invention, a part of a certain same equivalent crystallographic axis [at least] has turned to a direction the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation also of whose antiferromagnetism layer 4 and fixed magnetic layer 3 which were formed above the free magnetic layer 1, and they moreover exist in the aforementioned crystal face and which is mutually different by the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0269] Moreover, when the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, an interface sets the grain boundary of the aforementioned antiferromagnetism layer 4, and the grain boundary of the aforementioned fixed magnetic layer 3 in part at least, and they are in the discontinuous state.
[0270] For this reason, a part of aforementioned interface [at least] maintains a disconformity state, the suitable rule transformation is made by heat treatment, and the aforementioned antiferromagnetism layer 4 can acquire a big switched connection magnetic field.
[0271] In addition, it is desirable that the equivalent crystal face typically expressed in the direction parallel to antiferromagnetism layer 4 and fixed magnetic layer 3 film surface as [111] sides is carrying out priority orientation. Moreover, it is desirable to have turned to the direction where the directions of the equivalent crystallographic axis typically expressed as <110> directions in the aforementioned crystal face differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0272] Moreover, the equivalent crystal face typically expressed with this invention in the direction where the aforementioned antiferromagnetism layer 4 is parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned antiferromagnetism layer 4 in part at least, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. While being able to raise resistance rate of change by this, the aforementioned antiferromagnetism layer 4 is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire a big switched connection magnetic field. In addition, as for the interior angle between the aforementioned twin boundary and an interface,
it is desirable that it is 76 degrees or less at 68 degrees or more.
[0273] moreover, in the spin bulb type thin film shown in drawing 5 In the transparency electron-diffraction image of the antiferromagnetism layer 4 which was made to carry out incidence of the parallel shell electron ray (beam) to the aforementioned interface, and was obtained, and the fixed magnetic layer 3 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The diffraction mottle which is located in the direction of thickness when the indexing same among the aforementioned diffraction mottles at the

diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 is made and it sees from a beam zero and which shows a certain crystal face, The first imaginary line which connected the aforementioned beam zero is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.

[0274] And the second imaginary line which connected with this invention the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction], and which shows a certain crystal face, and the aforementioned beam zero when the same indexing was made and it saw from the aforementioned beam zero is mutually shifted in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or when it sees from the aforementioned beam zero, the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction] and which shows a certain crystal face appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.

[0275] As for the diffraction mottle located in the aforementioned thickness direction, in the above-mentioned case, it is desirable that the equivalent crystal face typically expressed as {111} sides is shown.

[0276] or in the spin bulb type thin film shown in drawing 5 In the transparency electron-diffraction image of the antiferromagnetism layer 4 which was made to carry out incidence of the electron ray (beam), and was obtained from the aforementioned interface and the perpendicular direction, and the fixed magnetic layer 3 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The imaginary line by which the same indexing was made by the diffraction figure of the antiferromagnetism layer 4 and the diffraction figure of the fixed magnetic layer 3 and which connected from a certain diffraction mottle to the beam zero is mutually shifted among the aforementioned diffraction mottles in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or the diffraction mottle to which a certain indexing was carried out among the aforementioned diffraction mottles appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.

[0277] In the above-mentioned case, a direction perpendicular to the aforementioned interface is the direction of the equivalent crystallographic axis typically expressed as <111> directions, or, as for the crystal face parallel to the aforementioned interface of an antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is the equivalent crystal face typically expressed as [111] sides.

[0278] If the above transparency electron-diffraction images are obtained, the same equivalent crystal face as a direction parallel to a film surface will carry out priority orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3, and it will be guessed that they are the thing which moreover exists in the aforementioned crystal face and which has turned to the direction where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3. Therefore, the aforementioned antiferromagnetism layer 4 has caused the suitable rule transformation with heat treatment as it is the spin bulb type thin film which has the above-mentioned transparency electron-diffraction image, and a big switched connection magnetic field is acquired compared with the former.

[0279] Drawing 6 and 7 are the cross sections showing the structure of the AMR type magnetoresistance-effect element of this invention. As shown in drawing 6 , the laminating of the lower shell soft-magnetism layer (SAL layer) 18, a non-magnetic layer (SHUNT layer) 19, and the magnetic-reluctance layer (MR layer) 20 is carried out continuously.

[0280] For example, the aforementioned soft-magnetism layer 18 is formed with a Fe-nickel-Nb alloy, and the non-magnetic layer 19 is formed for Ta film and the magnetic-reluctance layer 20 with the NiFe alloy.

[0281] On the aforementioned magnetic-reluctance layer 20, the exchange bias layers (antiferromagnetism layer) 21 and 21 are formed at the portion of the both sides of the direction of the width of recording track (the direction of X) which opened the width of recording track Tw. Although a conductive layer does not illustrate, it is formed, for example on the aforementioned exchange bias layers 21 and 21.

[0282] Moreover, in drawing 7 , the interval of the width of recording track Tw is opened in the direction of the width of recording track (the direction of illustration X), and the seed layer 22 of a couple is formed. The exchange bias layers 21 and 21 are formed on the aforementioned seed layer 22, and it is buried by the seed layer 22 of the aforementioned couple and the exchange bias layer 21, and the insulating layer 26 in which between 21 was formed by the insulating material of SiO2 or aluminum2O3 grade.

[0283] And the laminating of the magnetic-reluctance layer (MR layer) 20, a non-magnetic layer

(SHUNT layer) 19, and the soft-magnetism layer (SAL layer) 18 is carried out on the aforementioned exchange bias layers 21 and 21 and the aforementioned insulating layer 26.

[0284] In this invention, the same equivalent crystal face as a direction parallel to a film surface carried out priority orientation of the exchange bias layer 21 and the magnetic-reluctance layer 20 which are shown in drawing 6 and 7, and they have turned to the direction which moreover exists in the aforementioned crystal face and where a part of a certain same equivalent crystallographics axis at least] differ mutually in the aforementioned exchange bias layer 21 and the magnetic-reluctance layer 20.

[0285] Moreover, when the aforementioned exchange bias layer 21 and the magnetic-reluctance layer 20 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, an interface sets the grain boundary of the aforementioned exchange bias layer 21, and the grain boundary of the aforementioned magnetic-reluctance layer 20 in part at least, and they are in the discontinuous state.

[0286] For this reason, a part of aforementioned interface [at least] maintains a disconformity state, the suitable rule transformation is made by heat treatment, and the aforementioned exchange bias layer 21 can acquire a big switched connection magnetic field.

[0287] In addition, as for the exchange bias layer 21 and the magnetic-reluctance layer 20, it is desirable that the equivalent crystal face typically expressed in the direction parallel to a film surface as [111] sides is carrying out priority orientation. Moreover, it is desirable to have turned to the direction where the directions of the equivalent crystallographic axis typically expressed as <110> directions in the aforementioned crystal face differ mutually in the exchange bias layer 21 and the magnetic-reluctance layer 20.

[0288] Moreover, the equivalent crystal face typically expressed with this invention in the direction where the aforementioned exchange bias layer 21 is parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned exchange bias layer 21 in part at least, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. For this reason, the aforementioned exchange bias 21 is metamorphosing into the superlattice from the irregular grid appropriately, and can acquire a big switched connection magnetic field. In addition, as for the interior angle between the aforementioned twin boundary and an interface, it is desirable that it is 76 degrees or less at 68 degrees or more.

[0289] moreover, in the transparency electron-diffraction image of the exchange bias layer 21 which was made to carry out incidence of the electron ray (beam) to the aforementioned interface in drawing 6 and the AMR type thin film shown in 7 since it was parallel, and was obtained, and the magnetic-reluctance layer 20 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The diffraction mottle which is located in the direction of thickness when the indexing same among the aforementioned diffraction mottles at the diffraction figure of the exchange bias layer 21 and the diffraction figure of the magnetic-reluctance layer 20 is made and it sees from a beam zero and which shows a certain crystal face, The first imaginary line which connected the aforementioned beam zero is mutually in agreement by the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer.

[0290] And the second imaginary line which connected with this invention the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction], and which shows a certain crystal face, and the aforementioned zero when the same indexing was made and it saw from the aforementioned zero is mutually shifted in the diffraction figure of the aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or when it sees from the aforementioned beam zero, the diffraction mottle which is located in the direction of [other than the aforementioned thickness direction] and which shows a certain crystal face appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.

[0291] As for the diffraction mottle located in the aforementioned thickness direction, in the above-mentioned case, it is desirable that the equivalent crystal face typically expressed as {111} sides is shown.

[0292] or in drawing 6 and the AMR type thin film shown in 7 In the transparency electron-diffraction image of the exchange bias layer 21 which was made to carry out incidence of the electron ray (beam), and was obtained from the aforementioned interface and the perpendicular direction, and the magnetic-reluctance layer 20 The diffraction mottle corresponding to the reciprocal-lattice point of expressing each crystal face of each layer appears. The imaginary line by which the same indexing was made by the diffraction figure of the exchange bias layer 21 and the diffraction figure of the magnetic-reluctance layer 20 and which connected from a certain diffraction mottle to the beam zero is mutually shifted among the aforementioned diffraction mottles in the diffraction figure of the

aforementioned antiferromagnetism layer, and the diffraction figure of a ferromagnetic layer. Or the diffraction mottle to which a certain indexing was carried out among the aforementioned diffraction mottles appears only in one diffraction figure of an antiferromagnetism layer or a ferromagnetic layer.

[0293] In the above-mentioned case, a direction perpendicular to the aforementioned interface is the direction of the equivalent crystallographic axis typically expressed as <111> directions, or, as for the crystal face parallel to the aforementioned interface of an antiferromagnetism layer and a ferromagnetic layer, it is desirable that it is the equivalent crystal face typically expressed as [111] sides.

[0294] If the above transparency electron-diffraction images are obtained, it will be thought that the exchange bias layer 21 and the magnetic-reluctance layer 20 have turned to the direction which the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation, and moreover exists in the aforementioned crystal face and where a part of a certain same equivalent crystallographics axis [at least] differ mutually in the aforementioned exchange bias layer 21 and the magnetic-reluctance layer 20. And the aforementioned exchange bias layer 21 has caused the suitable rule transformation with heat treatment as it is the spin bulb type thin film which has the above-mentioned transparency electron-diffraction image, and a big switched connection magnetic field is acquired compared with the former.

[0295] In the AMR type thin film shown in above-mentioned drawing 6 and above-mentioned drawing 7
, E field of drawing 6 and the magnetic-reluctance layer 20 shown in 7 is formed into a single magnetic domain in the direction of illustration X by the switched connection magnetic field generated in the interface of the aforementioned exchange bias layers 21 and 21 and the magnetic-reluctance layer 20. And it is induced by this and magnetization of the D region of the aforementioned magnetic-reluctance layer 20 is arranged in the direction of illustration X. Moreover, the current magnetic field generated in case detection current flows the magnetic-reluctance layer 20 is impressed to the soft-magnetism layer 18 in the direction of Y, and a horizontal bias magnetic field is given to the D region of the magnetic-reluctance layer 20 in the direction of Y by the magnetostatic binding energy which the soft-magnetism layer 18 brings about. By giving this horizontal bias layer to the D region of the magnetic-reluctance layer 20 formed into the single magnetic domain in the direction of X, the resistance change (magnetoresistance-effect property : the H-R effect property) to magnetic field change of the D region of the magnetic-reluctance layer 20 is set as the state of having linearity.

[0296] The move direction of a record medium is a Z direction, if it leaks in the direction of illustration Y and a magnetic field is given, the resistance of the D region of the magnetic-reluctance layer 20 will change, and this will be detected as voltage change.

[0297] In addition, although it is about the manufacture method of the magnetoresistance-effect element shown in above-mentioned drawing 1 or above-mentioned drawing 7 , it is desirable to form the antiferromagnetism layer 4 as follows especially in this invention.

[0298] As described above, as for the element X of the aforementioned antiferromagnetism layer 4, or the composition ratio of element X+X', it is desirable that it is below 60 (at%) more than 45 (at%), and as shown in the experimental result later mentioned as it is below 56.5 (at%) more than 49 (at%) and is this within the limits, it can acquire a big switched connection magnetic field more preferably.

[0299] Therefore, what is necessary is just to perform heat treatment, after being above-mentioned composition within the limits, forming the aforementioned antiferromagnetism layer 4 in a membrane formation stage as one process and each class of further others also forming membranes.

[0300] In this invention, it sets after heat treatment. Moreover, the interface of the antiferromagnetism layer 4 and the fixed magnetic layer 3, When the interface of the exchange bias layer 16 and the free magnetic layer 1, the interface of the exchange bias layer 21 and the magnetic-reluctance layer 20, and the seed layer 22 are formed Although it is desirable that it is in a disconformity state as for a part of interface of the aforementioned seed layer 22 and the antiferromagnetism layer 4, and interface [at least] of the aforementioned seed layer 22 and the exchange bias layers 16 and 21, as for the aforementioned disconformity state, being maintained from the membrane formation stage is desirable. It is because it is thought that the aforementioned antiferromagnetism layer 4 grade cannot cause a suitable rule transformation easily even if it heat-treats that the aforementioned interface is in an adjustment state in a membrane formation stage.

[0301] In order to make the aforementioned interface into the disconformity state in the membrane formation stage, it is desirable to form the aforementioned antiferromagnetism layer 4 grade, for example by the following methods.

[0302] Drawing 8 is the ** type view showing the state where each class of the cascade screen shown in drawing 1 was formed. As shown in drawing 8 , after forming the seed layer 22 on the ground layer 6, the aforementioned antiferromagnetism layer 4 is formed by three layer membranes. The 1st antiferromagnetism layer 23 which constitutes the aforementioned antiferromagnetism layer 4, the 2nd antiferromagnetism layer 24, and the 3rd antiferromagnetism layer 25 are formed with the above-mentioned X-Mn alloy and the above-mentioned X-Mn-X' alloy.
[0303] However, in a membrane formation stage, the element X which constitutes the 1st and 3rd antiferromagnetism layers 23 and 25, or the composition ratio of element X+X' is made [more] than the element X of the 2nd antiferromagnetism layer 24, or the composition ratio of element X+X'.
[0304] Moreover, the 2nd antiferromagnetism layer 24 formed between the antiferromagnetism layer 23 of the above 1st and the 3rd antiferromagnetism layer 25 is formed with the antiferromagnetism material near the ideal composition which is easy to metamorphose into a superlattice with heat treatment from an irregular grid.
[0305] Thus, when heat-treating, making the element X of the 1st antiferromagnetism layer 23 and the 3rd antiferromagnetism layer 25, or the composition ratio of element X+X' larger than the element X of the 2nd antiferromagnetism layer 24, or the composition ratio of element X+X' In order that the antiferromagnetism layer 4 may make the transformation to a superlattice from an irregular grid easy to carry out, in a field side, it is because it is necessary to make it not restrained by the crystal structure of the aforementioned fixed magnetic layer 3 and the seed layer 22 etc.
[0306] As for the element X of the antiferromagnetism layer 23 of the above 1st, and the 3rd antiferromagnetism layer 25, or the composition ratio of element X+X', it is desirable that it is below 65 (at%) more than 53 (at%), and it is below 60 (at%) more than 55 (at%) more preferably. Moreover, as for the thickness of the antiferromagnetism layer 23 of the above 1st, and the 3rd antiferromagnetism layer 25, it is desirable that it is [3A or more] 30A or less. For example, by the case of drawing 8 , the above 1st and the 3rd antiferromagnetism layer 23 and 25 are formed by about 10A, respectively.
[0307] The element X of the antiferromagnetism layer 24 of the above 2nd or the composition ratio of element X+X' is formed below by 57 (at%) more than 44 (at%). Preferably, it is below 55 (at%) more than 46 (at%). If Element X or the composition ratio of element X+X' is formed within the limits of this, the antiferromagnetism layer 24 of the above 2nd will become easy to metamorphose into a superlattice by heat-treating from an irregular grid. In addition, as for the thickness of the antiferromagnetism layer 24 of the above 2nd, it is desirable that it is 70A or more. In addition, in the case of the example shown in drawing 8 , the thickness of the antiferromagnetism layer 24 of the above 2nd is formed by about 100A.
[0308] Moreover, it is desirable to form each above-mentioned antiferromagnetism layers 23, 24, and 25 by the spatter. In addition, it is desirable at this time to form the 1st and 3rd antiferromagnetism layers 23 and 25 with low spatter gas pressure rather than the 2nd antiferromagnetism layer 24. It is possible to make the element X of the above 1st and the 3rd antiferromagnetism layer 23 and 25 or the composition ratio of element X+X' by this larger than the element X of the 2nd antiferromagnetism layer 24 or the composition ratio of element X+X'.
[0309] Or even when it does not form by this invention by three layer membranes which described the aforementioned antiferromagnetism layer 4 above in the membrane formation stage (before heat treatment) but the aforementioned antiferromagnetism layer 4 is formed by the monolayer by the following methods, it is possible to change appropriately Element X or the composition ratio (atomic %) of element X+X' in the direction of thickness, and to form it in it.
[0310] In case the antiferromagnetism layer 4 is formed by the spatter using the antiferromagnetism material which contains Elements X and Mn first, or the target formed from Element X, X', and Mn Spatter gas pressure is gradually made high, the antiferromagnetism layer 4 is formed, it is the stage which carried out half grade membrane formation of the aforementioned antiferromagnetism layer 4, and shortly, the aforementioned spatter gas pressure is gradually made low, and the remaining antiferromagnetism layers 4 are formed as it separates from the seed layer 22.
[0311] According to this method, it becomes low gradually, composition applying [Element X or / of element X+X'] it near the center of the thickness of the aforementioned antiferromagnetism layer 4 from an interface with the seed layer 22 (atomic %), and it becomes high gradually, composition applying [aforementioned] it to an interface with the aforementioned fixed magnetic layer 3 from near [aforementioned] a center (atomic %).
[0312] For this reason, Element X or the composition ratio (atomic %) of element X+X' is [near the interface with the seed layer 22 and the fixed magnetic layer 3] the largest, and it becomes possible to form the antiferromagnetism layer 4 to which thickness becomes almost the lowest near a center.

[0313] In addition, when the composition ratio of all the elements that constitute the aforementioned antiferromagnetism layer 4 is made into 100at(s)% near the interface with the seed layer 22 near the interface with the aforementioned fixed magnetic layer 3, it is desirable to make Element X or the composition ratio of element X+X' into less than [more than 53at%65at%], and it is less than [more than 55at%60at%] more preferably.
[0314] Moreover, near the center of the direction of thickness of the antiferromagnetism layer 4, it is desirable to make the aforementioned element X or the composition ratio of element X+X' below into 57 (at%) more than 44 (at%), and it is below 55 (at%) more than 46 (at%) more preferably.
Moreover, it is desirable to form the thickness of the aforementioned antiferromagnetism layer 4 by 76A or more.
[0315] Drawing 9 is the ** type view of a spin bulb type thin film showing the state after heat-treating to the cascade screen shown in drawing 8 .
[0316] In this invention, to the side which touches the aforementioned seed layer 22 and the fixed magnetic layer 3 as mentioned above The 1st and 3rd antiferromagnetism layers 23 and 25 with many Elements X or the composition ratios of element X+X' are formed. And since the 2nd antiferromagnetism layer 24 formed between the above 1st and the 3rd antiferromagnetism layer 23, and 25 by the composition which is easy to metamorphose into a superlattice with heat treatment from an irregular grid appropriately is formed At the same time a transformation progresses in the portion of the antiferromagnetism layer 24 of the above 2nd with heat treatment It is thought that composition diffusion takes place between the 1st and 3rd antiferromagnetism layers 23 and 25 and the 2nd antiferromagnetism layer 24. Therefore, also in the portions of the above 1st and the 3rd antiferromagnetism layer 23 and 25, maintaining a disconformity state appropriately by the interface with the seed layer 22 and the fixed magnetic layer 3, the transformation to a superlattice from an irregular grid takes place, and a suitable transformation can be caused by the antiferromagnetism layer 4 whole.
[0317] And in the spin bulb type thin film after heat treatment, the same equivalent crystal face as a direction parallel to a film surface carried out priority orientation of the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3, and they have turned to the direction which moreover exists in the aforementioned crystal face and where a part of a certain same equivalent crystallographics axis [at least] differ mutually by the antiferromagnetism layer 4 and the fixed magnetic layer 3.
[0318] Moreover, when the aforementioned antiferromagnetism layer 4 and the fixed magnetic layer 3 are seen as a cross section from a direction (illustration Z direction) parallel to thickness, an interface sets the grain boundary of the aforementioned antiferromagnetism layer 4, and the grain boundary of the aforementioned fixed magnetic layer 3 in part at least, and they are in the discontinuous state.
[0319] Moreover, since the seed layer is formed in the bottom of the aforementioned antiferromagnetism layer 4 in this invention, the equivalent crystal face typically expressed in the direction where the aforementioned antiferromagnetism layer is parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned antiferromagnetism layer 4 in part at least, and the twin boundary of a part of aforementioned twin crystal is un-parallel to the aforementioned interface. In addition, as for the interior angle between the aforementioned twin boundary and an interface, it is desirable that it is 76 degrees or less at 68 degrees or more. It is still more desirable that the equivalent crystal face expressed as [111] sides is carrying out priority orientation also of the aforementioned fixed magnetic layer 3.
[0320] In addition, the ratio of atomic % of the element X to Mn or element X+X' is considered that the increasing field exists by the antiferromagnetism layer 4 after heat treatment as it goes to the seed layer 22 and the fixed magnetic layer 3.
[0321] Although you may form by three layer membranes which described the antiferromagnetism layer 4 above in the case of the spin bulb type thin film shown in drawing 2 , you may form with the two-layer structure of the 2nd antiferromagnetism layer 24 which touches a 1st antiferromagnetism layer [which touches the fixed magnetic layer 3 side, for example] 23, and protective-layer 7 side. It is because there is no seed layer 22 like drawing 1 at drawing 2 .
[0322] In addition, when the antiferromagnetism layer 4 is formed by the two-layer film as mentioned above, it is considered by the antiferromagnetism layer 4 after heat treatment for the field which the ratio of atomic % of the element X to Mn or element X+X' increases to exist as it goes to the fixed magnetic layer 3.
[0323] Moreover, in the case of the spin bulb type thin film of drawing 3 , the exchange bias layer 16 is formed by the two-layer film like the case of drawing 2 . The 1st antiferromagnetism layer 23 is

formed in contact with the free magnetic layer 1 side, and forms the 2nd antiferromagnetism layer 24 in the side which is separated from the aforementioned free magnetic layer 1.
[0324] Moreover, the antiferromagnetism layer 4 shown in drawing 3 is formed by three layer membranes like the case of drawing 1 . By heat-treating, a suitable rule transformation is caused and the aforementioned exchange bias layer 16 and the antiferromagnetism layer 4 can acquire a big switched connection magnetic field.
[0325] It is considered by the aforementioned exchange bias layer 16 after heat treatment for the field which the ratio of atomic % of the element X to Mn or element X+X' increases to exist as it goes to the free magnetic layer 1.
[0326] Moreover, it is considered by the aforementioned antiferromagnetism layer 4 after heat treatment for the field which the ratio of atomic % of the element X to Mn or element X+X' increases to exist as it goes to the fixed magnetic layer 3 and the seed layer 22.
[0327] Moreover, in the manufacture method of a spin bulb type thin film shown in drawing 4 , the antiferromagnetism layer 4 is formed by the two-layer film like the case of drawing 2 . The 1st antiferromagnetism layer 23 is formed in contact with the fixed magnetic layer 3 side, and forms the 2nd antiferromagnetism layer 24 in the side which is separated from the aforementioned fixed magnetic layer 3.
[0328] Moreover, the exchange bias layer 16 is formed by three layer membranes like the case of the antiferromagnetism layer 4 of drawing 1 . By heat-treating, a suitable rule transformation is caused and the aforementioned exchange bias layer 16 and the antiferromagnetism layer 4 can acquire a big switched connection magnetic field.
[0329] It is considered by the aforementioned exchange bias layer 16 after heat treatment for the field which the ratio of atomic % of the element X to Mn or element X+X' increases to exist as it goes to the free magnetic layer 1 and the seed layer 22.
[0330] Moreover, it is considered by the aforementioned antiferromagnetism layer 4 after heat treatment for the field which the ratio of atomic % of the element X to Mn or element X+X' increases to exist as it goes to the fixed magnetic layer 3.
[0331] As shown in drawing 10 by the manufacture method of a dual spin bulb type thin film shown in drawing 5 The antiferromagnetism layer 4 located below the free magnetic layer 1 is formed by three layer membranes of the 1st antiferromagnetism layer 23, the 2nd antiferromagnetism layer 24, and the 3rd antiferromagnetism layer 25. The antiferromagnetism layer 4 located above the free magnetic layer 1 is formed by the two-layer film of the 1st antiferromagnetism layer 14 and the 2nd antiferromagnetism layer 15.
[0332] It is the same as the thickness of the antiferromagnetism layer 23 of the above 1st, the 2nd antiferromagnetism layer 24, and the 3rd antiferromagnetism layer 25, and the thing explained by drawing 1 about composition.
[0333] Heat treatment is performed, after forming membranes, as shown in drawing 10 . The state is expressed to drawing 11 . It is thought that the field which the ratio of atomic % of the element X to Mn or element X+X' increases exists as three layer membranes which constitute the antiferromagnetism layer 4 currently formed below the free magnetic layer 1 from drawing 11 cause composition diffusion and go to the aforementioned antiferromagnetism layer 4 after heat treatment at the fixed magnetic layer 3 and the seed layer 22.
[0334] Moreover, it is thought that the field which the ratio of atomic % of the element X to Mn or element X+X' increases exists as the two-layer film which constitutes the antiferromagnetism layer 4 formed above the free magnetic layer 1 also causes composition diffusion and goes to the aforementioned antiferromagnetism layer 4 after heat treatment at the fixed magnetic layer 3.
[0335] Next, in the manufacture method of the AMR type thin film shown in drawing 6 , it forms by the two-layer film like [magnetic layer / free / which shows the exchange bias layer 21 to drawing 10 / 1] the antiferromagnetism layer 4 formed in the illustration bottom. The aforementioned exchange bias layer 21 is formed in the 1st antiferromagnetism layer 14 which touches the magnetic-reluctance layer 20, and the 2nd antiferromagnetism layer 15 formed in the side which is separated from the aforementioned magnetic-reluctance layer 20.
[0336] If it heat-treats, the aforementioned exchange bias layer 21 will cause a suitable rule transformation, and a big switched connection magnetic field will generate it between the aforementioned exchange bias layer 21 and the magnetic-reluctance layer 20.
[0337] And it is considered by the aforementioned exchange bias layer 21 after heat treatment for the field which the ratio of atomic % of the element X to Mn or element X+X' increases to exist as it goes to the magnetic-reluctance layer 20.
[0338] Moreover, by the manufacture method of the AMR type thin film shown in drawing 7 , it forms by three layer membranes like the antiferromagnetism layer 4 which shows the exchange bias layer

21 to drawing 8 . The aforementioned exchange bias layer 21 is formed in the 2nd antiferromagnetism layer 24 formed between the 1st antiferromagnetism layer 23 which touches the magnetic-reluctance layer 20, the 3rd antiferromagnetism layer 25 which touches the seed layer 22, and the above 1st and the 3rd antiferromagnetism layer 23 and 25.
[0339] If it heat-treats, the aforementioned exchange bias layer 21 will cause a suitable rule transformation, and a big switched connection magnetic field will generate it between the aforementioned exchange bias layer 21 and the magnetic-reluctance layer 20.
[0340] And it is considered by the aforementioned exchange bias layer 21 after heat treatment for the field which the ratio of atomic % of the element X to Mn or element X+X' increases to exist as it goes to the magnetic-reluctance layer 20 and the seed layer 22.
[0341] Drawing 12 is the cross section with which the magnetoresistance-effect element shown in drawing 11 from drawing 1 was formed and which read and looked at the structure of a head from the opposed face side with a record medium.
[0342] A sign 40 is the lower shield layer formed for example, with the NiFe alloy etc., and the lower gap layer 41 is formed on this lower shield layer 40. Moreover, on the lower gap layer 41, the magnetoresistance-effect element 42 shown in drawing 1 or drawing 7 is formed, further, the up gap layer 43 is formed on the aforementioned magnetoresistance-effect element 42, and the up shield layer 44 formed with the NiFe alloy etc. is formed on the aforementioned up gap layer 43.
[0343] The aforementioned lower gap layer 41 and the up gap layer 43 are formed of insulating materials, such as SiO2 and aluminum 2O3 (alumina). As shown in drawing 12 , the length from the lower gap layer 41 to the up gap layer 43 is gap length Gl, and it can respond to high recording density-ization, so that this gap length Gl is small.
[0344] In this invention, even if it makes thickness of the antiferromagnetism layer 4 small, a still bigger switched connection magnetic field can be generated. Therefore, thickness of a magnetoresistance-effect element can be made small compared with the former, and it is possible to manufacture the thin film magnetic head which can respond to high recording density-ization by narrow gap-ization.
[0345] In addition, although the example which formed the seed layer 22 in the antiferromagnetism layer 4 (or exchange bias layer 16 or magnetic-reluctance layer 20) bottom in drawing 1 , drawing 3 , drawing 4 , drawing 5 , and drawing 7 was carried in this invention, it does not limit to this gestalt.
[0346] Moreover, in this invention, in the cutting plane cut in the direction parallel to the direction of thickness, although the grain boundary of the antiferromagnetism layer 4 and the grain boundary of a ferromagnetic layer are in the discontinuous state by a part of interface [at least], the different crystal face in the direction parallel to a film surface may be carrying out priority orientation of the crystal orientation of the aforementioned antiferromagnetism layer and a ferromagnetic layer in this case. Even in such a case, with heat treatment, a suitable rule transformation is caused and an antiferromagnetism layer can acquire a big switched connection magnetic field.
[0347]
[Example] In this invention, the spin bulb film of the film composition indicated below was formed, and the relation between the aforementioned amount of Pt(s) and a switched connection magnetic field (Hex) was investigated, changing the amount of Pt(s) of the PtMn alloy film which constitutes an antiferromagnetism layer.
[0348] Film composition A lower shell, Si substrate / alumina / ground layer : Ta (3nm) / seed layer : NiFe (3nm) / antiferromagnetism layer :P txMn 100-x It is Ta (3nm). (15nm) / fixed magnetic layer: -- [Co(1.5nm)/Ru(0.8nm)/Co (2.5nm)] / nonmagnetic interlayer: -- Cu (2.3nm) / free magnetic layer: -- [Co(1nm)/NiFe (3nm)] / BAKKUDO layer: -- Cu (1.5nm) / protective-layer: -- The numeric value of parenthesis writing indicated by each class shows thickness.
[0349] The aforementioned antiferromagnetism layer and the fixed magnetic layer were formed by the DC magnetron-sputtering method. Moreover, when forming the aforementioned antiferromagnetism layer and a fixed magnetic layer, Ar gas pressure was set to 1 - 3mTorr. Moreover, when forming the aforementioned antiferromagnetism layer, distance between a substrate and a target was set to 70-80mm. After forming the spin bulb film of the above-mentioned film composition, heat treatment of 2 hours or more was performed above 200 degrees C, and the switched connection magnetic field was measured. The experimental result is shown in drawing 13 .
[0350] As shown in drawing 13 , when the amount X of Pt(s) increases up to about 50 (at%) to 55 (at%) grade, it turns out that a switched connection magnetic field (Hex) also increases. Moreover, when the aforementioned amount X of Pt(s) becomes the about 55 (at%) above, it turns out that a switched connection magnetic field decreases gradually.
[0351] In this invention, the case where a switched connection magnetic field was acquired more than 1.58x104 (A/m) was made into the desirable amount of Pt(s), and the desirable amount of Pt(s)

was set up below 60 (at%) more than 45 (at%) from the experimental result shown in drawing 13 .
[0352] Moreover, in this invention, the case where a switched connection magnetic field was acquired more than 7.9x104 (A/m) was made into the more desirable amount of Pt(s), and the more desirable amount of Pt(s) was set up below 56.5 (at%) more than 49 (at%) from the experimental result shown in drawing 13 .
[0353] It is thought that change appears in the size of a switched connection magnetic field with the amount of Pt(s) as mentioned above for the state of the interface of an antiferromagnetism layer and a ferromagnetic layer (fixed magnetic layer) changing by changing the amount of Pt(s).
[0354] The amount of Pt(s) understands the bird clapper for the lattice constant of an antiferromagnetism layer greatly indeed here, if it increases. For this reason, the interface of the aforementioned antiferromagnetism layer and a ferromagnetic layer can be made easy to be able to extend the difference of the lattice constant of an antiferromagnetism layer and a ferromagnetic layer, and to change into a disconformity state by making [many] the amount of Pt(s).
[0355] It becomes [by on the other hand forming a seed layer in the antiferromagnetism layer bottom like the above-mentioned film composition] that it is easy to make the priority orientation of the [111] sides carry out in the direction parallel to a film surface like the aforementioned seed layer about the crystal orientation of each class, such as an antiferromagnetism layer formed on the aforementioned seed layer.
[0356] Moreover, as there are many amounts of Pt(s), they are not necessarily better. When the amount of Pt(s) is made [many] too much, the aforementioned antiferromagnetism layer is because a suitable rule transformation cannot be caused even if it heat-treats.
[0357] An interface with a ferromagnetic layer is formed by the composition which is easy to maintain at a disconformity state that it is easy to cause a rule transformation for the amount of Pt(s) which constitutes having covered the antiferromagnetism layer bottom with the seed layer, and an antiferromagnetism layer from this invention. When it heat-treats by controlling appropriately the membrane formation conditions furthermore described above etc., the aforementioned antiferromagnetism layer In the state after causing a suitable rule transformation, maintaining a disconformity state by the interface with a ferromagnetic layer and heat-treating The aforementioned antiferromagnetism layer and the ferromagnetic layer serve as crystal orientation which the same equivalent crystal face as a direction parallel to a film surface carries out priority orientation, and exists in the aforementioned crystal face and which turns to the direction where a part of directions [at least] of a certain same equivalent crystallographic axis differ mutually in the aforementioned antiferromagnetism layer and a ferromagnetic layer.
[0358] Moreover, if the cutting plane which cut the aforementioned antiferromagnetism layer and the ferromagnetic layer from the direction parallel to thickness is observed, the grain boundary of the aforementioned antiferromagnetism layer and the grain boundary of a ferromagnetic layer are in the discontinuous state by a part of interface [at least] of the aforementioned antiferromagnetism layer and a ferromagnetic layer.
[0359] Moreover, in this invention, the equivalent crystal face typically expressed in the direction where the aforementioned antiferromagnetism layer and a fixed magnetic layer are parallel to the aforementioned interface as [111] sides carries out priority orientation, moreover, twin crystal is formed in the aforementioned antiferromagnetism layer 4 in part at least, and the twin boundary of a part of aforementioned twin crystal becomes un-parallel to the aforementioned interface.
[0360]
[Effect of the Invention] As explained in full detail above, the grain boundary formed in the aforementioned antiferromagnetism layer which appears the aforementioned switched connection film in a cutting plane parallel to the direction of thickness by the switched connection film in this invention, and the grain boundary formed in the ferromagnetic layer are discontinuous at a part of aforementioned interface [at least].
[0361] Moreover, in this invention, the equivalent crystal face expressed in the direction parallel to the aforementioned interface as [111] sides carries out priority orientation of the aforementioned antiferromagnetism layer, twin crystal is formed in the aforementioned antiferromagnetism layer in part at least, and the twin boundary of a part of [at least] aforementioned twin crystal of the aforementioned twin crystal is characterized by being formed in aforementioned being the interface and being un-parallel. In addition, as for the interior angle between the aforementioned twin boundary and the aforementioned interface, it is desirable that it is 76 degrees or less at 68 degrees or more.
[0362] When the above-mentioned membrane structure is obtained by the heat treatment back, the aforementioned antiferromagnetism layer is metamorphosing into the superlattice from the irregular grid appropriately with heat treatment, and can acquire a big switched connection magnetic field.
[0363] The above-mentioned switched connection film can be applied to various

magnetoresistance-effect elements, and it becomes possible to correspond appropriately that it is the magnetoresistance-effect element which has the aforementioned switched connection film to future high recording density-ization.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The cross section which looked at the structure of the single spin bulb type magnetoresistance-effect element of the 1st operation gestalt of this invention from the ABS side side,
[Drawing 2] The cross section which looked at the structure of the single spin bulb type magnetoresistance-effect element of the 2nd operation gestalt of this invention from the ABS side side,
[Drawing 3] The cross section which looked at the structure of the single spin bulb type magnetoresistance-effect element of the 3rd operation gestalt of this invention from the ABS side side,
[Drawing 4] The cross section which looked at the structure of the single spin bulb type magnetoresistance-effect element of the 4th operation gestalt of this invention from the ABS side side,
[Drawing 5] The cross section which looked at the structure of the dual spin bulb type magnetoresistance-effect element of the 5th operation gestalt of this invention from the ABS side side,
[Drawing 6] The cross section which looked at the structure of the AMR type magnetoresistance-effect element of the 6th operation gestalt of this invention from the ABS side side,
[Drawing 7] The cross section which looked at the structure of the AMR type magnetoresistance-effect element of the 7th operation gestalt of this invention from the ABS side side,
[Drawing 8] The ** type view showing the state of the membrane formation stage of the magnetoresistance-effect element shown in drawing 1 ,
[Drawing 9] The ** type view showing the structure of the aforementioned cascade screen after heat-treating to the cascade screen shown in drawing 8 ,
[Drawing 10] The ** type view showing the state of the membrane formation stage of the magnetoresistance-effect element shown in drawing 5 ,
[Drawing 11] The ** type view showing the structure of the aforementioned cascade screen after heat-treating to the cascade screen shown in drawing 10 ,
[Drawing 12] The structure **** fragmentary sectional view of the thin film magnetic head (reproducing head) in this invention,
[Drawing 13] The graph which shows the relation of the aforementioned amount of Pt(s) and switched connection magnetic field (Hex) at the time of changing the amount of Pt(s) of an antiferromagnetism layer (PtMn alloy film),
[Drawing 14] Drawing having shown the crystal orientation of the antiferromagnetism layer of a switched connection film and the ferromagnetic layer in this invention in ** type view,
[Drawing 15] Drawing having shown the crystal orientation of the antiferromagnetism layer of a switched connection film and the ferromagnetic layer in the example of comparison in ** type view,
[Drawing 16] The transparency electron-diffraction image of the film surface of a spin bulb film, and a parallel shell in this invention,
[Drawing 17] The transparency electron-diffraction image of the film surface of a spin bulb film, and a parallel shell in the example of comparison,
[Drawing 18] The ****** type view of the transparency electron-diffraction image shown in drawing 16 ,
[Drawing 19] The ****** type view of the transparency electron-diffraction image shown in drawing 17 ,
[Drawing 20] The ** type view of the transparency electron-diffraction image from the film surface and perpendicular direction of the antiferromagnetism layer in this invention,
[Drawing 21] The ** type view of the transparency electron-diffraction image from the film surface and perpendicular direction of the ferromagnetic layer in this invention,
[Drawing 22] The ** type view on top of which drawing 20 and the transparency electron-diffraction image of 21 were laid,
[Drawing 23] The ** type view of the transparency electron-diffraction image from the film surface and perpendicular direction of the antiferromagnetism layer in the example of comparison,
[Drawing 24] The ** type view of the transparency electron-diffraction image from the film surface and perpendicular direction of the ferromagnetic layer in the example of comparison,
[Drawing 25] The ** type view on top of which drawing 23 and the transparency electron-diffraction image of 24 were laid,
[Drawing 26] The transmission-electron-microscope photograph of the aforementioned cutting plane at the time of cutting the spin bulb type thin film in this invention from a direction parallel to thickness,
[Drawing 27] The transmission-electron-microscope photograph of the aforementioned cutting plane at the time of cutting the spin bulb type thin film in the example of comparison from a direction parallel to thickness,
[Drawing 28] The ****** type view of the transmission-electron-microscope photograph shown in drawing 26 ,
[Drawing 29] The ****** type view of the transmission-electron-microscope photograph shown in drawing 27 ,
[Drawing 30] The transmission-electron-microscope photograph of the aforementioned cutting plane at the time of cutting the spin bulb type thin film of another example in this invention from a direction parallel to thickness,
[Drawing 31] The ****** type view of the transmission-electron-microscope photograph shown in drawing 30 .
[Description of Notations]
1 Free Magnetic Layer
2 Nonmagnetic Interlayer
3 Fixed Magnetic Layer (Ferromagnetic Layer)

4 Antiferromagnetism Layer
5 Hard Bias Layer
6 Ground Layer
7 Protective Layer
8 Conductive Layer
14 23 1st antiferromagnetism layer
15 24 2nd antiferromagnetism layer
16 21 Exchange bias layer
17 26 Insulating layer
18 Soft-Magnetism Layer (SAL Layer)
19 Non-magnetic Layer (SHUNT Layer)
20 Magnetic-Reluctance Layer (MR Layer)
22 Seed Layer
25 3rd Antiferromagnetism Layer
42 Magnetoresistance-Effect Element

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] In the switched connection film with which an antiferromagnetism layer and a ferromagnetic layer touch, and are formed, a switched connection magnetic field occurs in the interface of the aforementioned antiferromagnetism layer and a ferromagnetic layer, and the magnetization direction of the aforementioned ferromagnetic layer is carried out in the fixed direction The aforementioned antiferromagnetism layer is formed with the antiferromagnetism material containing Elements X (however, X is one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn. The switched connection film characterized by the grain boundary formed in the aforementioned antiferromagnetism layer which appears in a cutting plane parallel to the direction of thickness in the aforementioned switched connection film and the grain boundary formed in the ferromagnetic layer being discontinuous at a part of aforementioned interface [at least].
[Claim 2] The aforementioned antiferromagnetism layer and a ferromagnetic layer are a switched connection film according to claim 1 in which the equivalent crystal face expressed in the direction parallel to the aforementioned interface as [111] sides is carrying out priority orientation.
[Claim 3] In the switched connection film with which an antiferromagnetism layer and a ferromagnetic layer touch, and are formed, a switched connection magnetic field occurs in the interface of the aforementioned antiferromagnetism layer and a ferromagnetic layer, and the magnetization direction of the aforementioned ferromagnetic layer is carried out in the fixed direction It is the switched connection film which the equivalent crystal face expressed in the direction parallel to the aforementioned interface as [111] sides carries out priority orientation of the aforementioned antiferromagnetism layer, and is characterized by forming twin crystal in the aforementioned antiferromagnetism layer in part at least, and forming the twin boundary of a part of [at least] aforementioned twin crystal in aforementioned being the interface and being un-parallel.
[Claim 4] The interior angle between the aforementioned twin boundary and the aforementioned interface is a switched connection film according to claim 3 which is 76 degrees or less at 68 degrees or more.
[Claim 5] The aforementioned ferromagnetic layer is a switched connection film according to claim 3 or 4 in which the equivalent crystal face expressed in the direction parallel to the aforementioned interface as [111] sides is carrying out priority orientation.
[Claim 6] The aforementioned antiferromagnetism layer is a switched connection film according to claim 3 to 5 formed with the antiferromagnetism material containing Elements X (however, X is one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn.
[Claim 7] The aforementioned switched connection film is a switched connection film according to claim 1 to 6 with which the seed layer the laminating was carried out to the order of a lower shell antiferromagnetism layer and a ferromagnetic layer, and the equivalent crystal face as which the crystal structure changes mainly from a face-centered cubic to the aforementioned antiferromagnetism layer bottom, and is moreover further expressed in the direction parallel to the aforementioned interface in it as [111] sides carried out [the layer] priority orientation is formed.
[Claim 8] The aforementioned seed layer is a NiFe alloy, nickel or nickel-Fe-Y alloy (however, at least one or more sorts as which Y is chosen from Cr, Rh, Ta, Hf, Nb, Zr, and Ti), and a switched connection film according to claim 7 further formed with nickel-Y alloy.
[Claim 9] It is the switched connection film according to claim 8 whose rate y of an atomic ratio, as for the aforementioned seed layer, an empirical formula is shown by 1(nickel1-xFex)-yYy (x and y are a rate of an atomic ratio), the rate x of an atomic ratio is 0.3 or less or more in zero, and is 0.5 or less or more in zero.
[Claim 10] The aforementioned seed layer is a switched connection film according to claim 7 to 9 which is nonmagnetic in ordinary temperature.
[Claim 11] The switched connection film according to claim 7 to 10 with which the ground layer formed by at least one or more sorts of elements among Ta, Hf, Nb, Zr, Ti, Mo, and W is formed in the bottom of the aforementioned seed layer.
[Claim 12] A part of interface [at least] of the aforementioned antiferromagnetism layer and a seed layer is the switched connection film according to claim 7 to 11 which is in a disconformity state.
[Claim 13] The aforementioned antiferromagnetism layer is a X-Mn-X' alloy (however, element X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements -- one sort or two sorts or more of elements -- it is -- the switched connection film according to claim 1 to 12 currently formed
[Claim 14] The aforementioned X-Mn-X' alloy is a switched connection film according to claim 13 a part of whose lattice point of the crystal lattice which consists of elements X and Mn it is the interstitial solid solution by which element X' trespassed upon the crevice between the space lattices which consist of elements X and Mn, or is the substitution solid solution replaced by element X'.
[Claim 15] The aforementioned element X or the composition ratio of element X+X' is a switched connection film according to claim 1 to 14 which is below 60 (at%) more than 45 (at%).
[Claim 16] A part of interface [at least] of the aforementioned antiferromagnetism layer and a ferromagnetic layer is the switched connection film according to claim 1 to 15 which is in a disconformity state.
[Claim 17] The magnetoresistance-effect element which is equipped with the following and characterized by forming the fixed magnetic layer formed in contact with the aforementioned antiferromagnetism layer and this

antiferromagnetism layer with the switched connection film indicated by either the claim 1 or the claim 16. Antiferromagnetism layer The fixed magnetic layer to which it is formed in in contact with this antiferromagnetism layer, and the magnetization direction is fixed by the exchange-anisotropy magnetic field with the aforementioned antiferromagnetism layer The free magnetic layer formed in the aforementioned fixed magnetic layer through the nonmagnetic interlayer The bias layer which arranges the magnetization direction of the aforementioned free magnetic layer in the magnetization direction of the aforementioned fixed magnetic layer, and the crossing direction
[Claim 18] The magnetoresistance-effect element which is equipped with the following, and the interval of the width of recording track Tw is vacated for the aforementioned free magnetic layer top or bottom, the exchange bias layer of antiferromagnetism is formed, and the aforementioned exchange bias layer and a free magnetic layer are formed with the switched connection film indicated by either the claim 1 or the claim 16, and is characterized by carrying out magnetization of the aforementioned free magnetic layer in the fixed direction. Antiferromagnetism layer The fixed magnetic layer to which it is formed in in contact with this antiferromagnetism layer, and the magnetization direction is fixed by the exchange-anisotropy magnetic field with the aforementioned antiferromagnetism layer The free magnetic layer formed in the aforementioned fixed magnetic layer through the nonmagnetic interlayer
[Claim 19] The magnetoresistance-effect element which is equipped with the following and characterized by forming the fixed magnetic layer formed in contact with the aforementioned antiferromagnetism layer and this antiferromagnetism layer with the switched connection film indicated by either the claim 1 or the claim 16. The nonmagnetic interlayer by whom the laminating was done to the upper and lower sides of a free magnetic layer The fixed magnetic layer located on one aforementioned nonmagnetic interlayer and under the nonmagnetic interlayer of another side The antiferromagnetism layer which is located on one aforementioned fixed magnetic layer and under the fixed magnetic layer of another side, and fixes the magnetization direction of each fixed magnetic layer in the fixed direction by the exchange-anisotropy magnetic field The bias layer which arranges the magnetization direction of the aforementioned free magnetic layer in the magnetization direction of the aforementioned fixed magnetic layer, and the crossing direction
[Claim 20] The magnetoresistance-effect element characterized by having the magnetic-reluctance layer and soft-magnetism layer which were piled up through the non-magnetic layer, vacating the interval of the width of recording track Tw for the aforementioned magnetic-reluctance layer top or bottom, forming an antiferromagnetism layer, and forming the aforementioned antiferromagnetism layer and the magnetic-reluctance layer with the switched connection film indicated by either the claim 1 or the claim 16.
[Claim 21] The thin film magnetic head characterized by forming the shield layer in the upper and lower sides of the magnetoresistance-effect element indicated by a claim 17 or either of 20 through a gap layer.

[Translation done.]